HECTOR · ROCKY MOUNTAINS

Hector, J.

On the geology of the country between Lake Superior and the Pacific

stood that these silent *undulatory* movements of the land are confined to the coasts and estuaries: they are manifest on the borders of the rivers and the great lakes of Canada, and also on the tributaries of the Mississippi. Slight shocks of earthquakes are common in Canada and the United States; but it does not appear, in the history of those countries, that any material change in the relative levels of certain tracts has been effected thereby. Admitting, however, that earthquakes have been the cause of sudden sinkings and elevations of the land, and which would produce anomalous results, there is a slow and constant undulatory movement of the earth's surface, which no doubt acts as much on the ocean's bed as upon the dry land.

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2. *On the* Geology *of the* Country *between* Lake Superior *and the* Pacific Ocean (*between the 48th and 54th parallels of latitude*), *visited by the* Government Exploring Expedition *under the command of* Captain J. Palliser (1857–60). By James Hector, M.D.

(Communicated by Sir R. I. Murchison, V.P.G.S.)

[Plate XIII.]

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Introduction.—In the spring of 1857 Her Majesty's Government, at the suggestion of the Royal Geographical Society, constituted an expedition to explore the British Territories in North America lying in the neighbourhood of the boundary-line of the United States, and stretching westward from Lake Superior. Public attention was at that time directed to the nature and resources of the vast territory which had been ceded to the keeping of the Hudson's Bay Fur Company, as there was a prospect of its being to some extent thrown open to colonization by the lapse of part of that Company's rights.

Principally through the efforts of Sir Roderick Murchison (at that time President of the Royal Geographical Society), General Sabine (acting for the Royal Society), Sir W. Hooker and Dr. Hooker, and of Mr. Ball (then Under-Secretary of State for the Colonies), the Expedition was organized and committed to the charge of Captain

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REFERENCE
Metamorphic Rocks and Granite.
Volcanic Rocks.
Carboniferous Limestone.
Devonian Limestone.
Everywhere covered with dense Forrest
NANAIMO
Nanaimo Harbour
Douglas I.
Newcastle I.
Lake Winipeg
Hudson Bay
Rocky Mountains.
Cascade Mountains.
Vancouver I.
unexplored
Boundary-line

Palliser, whose previous adventurous travels in that region had given assurance of the ability and energy necessary to penetrate unexplored country, and to preserve a friendly footing with the savage tribes that were to be encountered.

I was selected by Sir Roderick Murchison to accompany this Expedition in the combined capacity of surgeon and geologist; and, at the request of Government, he furnished me with instructions as to how I should turn to best advantage my opportunities for geological research.

The more important results of my work I have now the honour to communicate through him to this Society.

They have been accumulated during three years' travel in wild regions uninhabited save by Indians, or, at rare intervals, by little communities of persons engaged in the fur-trade. Excepting in the maps of Mr. Arrowsmith, which gave very correctly, on the whole, the great general features of the region explored, embracing 33° of longitude, and in some places 5° of latitude, nothing was known of its topography; so that this essential to sound geological reasoning had to be acquired step by step as the country was examined. I therefore submit my observations only as the best I could make under the circumstances, knowing that a re-examination of the country with the aid of the topographical details which we now possess would materially alter many of the views I have expressed.

Our previous knowledge concerning the geology of the interior of British North America was confined to the observations of Sir John Richardson, made during his three great overland arctic expeditions—the first two with Sir John Franklin, and the last in search of that lamented traveller. His published descriptions of the country he passed through are models of minute observation and cautious inference. To him we owe the first discovery of Silurian strata resting on a primitive axis stretching to the north-west from Lake Superior to the Arctic Ocean, and overlain by Devonian strata. He also showed the Rocky Mountains, where he met them on the Mackenzie River, to be composed of Carboniferous Limestone for the most part, which is also their character, we shall find, further to the south. From Elk River he brought home fossils which, although from a group of strata which he classes as Devonian, yet in a foot-note, on the authority of Sowerby, he says have quite a Jurassic aspect. That he was right in the latter suggestion is rendered probable by the recent publication of species of *Ammonites* by Mr. Hind, which were procured from that locality by the fur-traders, and which Messrs. Meek and Hayden consider to be of Jurassic age. Sir John Richardson also described the existence of a great lignite-basin in the valley of the Mackenzie River, which he classes as of Tertiary age.

The line of route, however, followed by Richardson did not, with the exception of the canoe-route from Lake Superior to Lake Winnipeg, and again at Fort Carlton on the Saskatchewan, touch on the country which has been explored by this Expedition. With regard to the canoe-route, I have added nothing to the researches of that traveller, and to the still more minute observations of Dr. Bigsby, which were

some years ago communicated to this Society. In 1855 Mr. A. K. Isbister communicated to this Society a useful and concise recapitulation of what had been written concerning the geology of the Hudson's Bay Territories, without adding anything, however, to our knowledge of the central district with which I have principally to deal. It is to Mr. Hind alone, who was in command of the Canadian Expedition to explore part of Rupert's Land, that I can refer in confirmation of my observations in any part of the prairie-regions. Mr. Hind in 1858 partially travelled over nearly the same ground as that traversed by our Expedition during the previous summer, but only as far as the elbow of the South Saskatchewan, and in regard to all essentials our work agrees exactly*.

Mr. Hind's report is valuable from his having had his fossils examined by Messrs. Meek and Hayden, whose labours in the Upper Missouri country and Western States since 1852 have given us most of the knowledge which we possess concerning the classification of the strata composing the northern part of the great American prairies; and to those gentlemen I shall have frequent occasion to refer.

Concerning the mass of the country explored, consisting of the prairies within the British possessions and the Rocky Mountains between latitude 49° and 53°, and of the country westward to Fort Colvile, I am not aware of anything having been published, excepting a few general remarks collected by Richardson from the botanists Douglas and Drummond or from the fur-traders.

Concerning the geology of the Pacific Coast, in the neighbourhood of the 49th parallel, there are very interesting notes scattered through the various U.S. Senate-papers, by Mr. Gibb and Dr. Suckley, who were employed in the survey for the Pacific Railroad. The former gentleman is still working in that country, being attached to the North-west Boundary-Commission. There is also a short notice of the geology of Vancouver Island, by Mr. Bauerman, geologist to the British section of the same commission, published in the Geol. Soc. Journal for 1860.

GENERAL PHYSICAL FEATURES.

The prairie-country which I have principally to describe may be considered as forming the northern portion of a triangular space containing the plateau which occupies the central region of the North American continent, having for its sides, first, the Rocky Mountains; second, the Laurentian axis or "intermediate primitive belt" of Richardson; and third, the Alleghany Mountains.

A low indistinct water-shed 850 feet above the sea at its lowest point, and apparently undetermined by any disturbance of the rocky framework of this basin posterior to the deposit of its more unconsolidated contents, follows a line sometimes north and sometimes south of the 49th parallel of latitude (which is the Political Boundary-line), dividing the waters which flow to the Gulf of Mexico from those flowing to the Arctic Ocean.

* My first Report on the Geology of this district was dated December 14, 1857. See Parliamentary Papers, June 1859.

The route of the Expedition starting from Lake Superior, after crossing a spur of the eastern axis, traversed the northern part of the plateau to the Rocky Mountains, and thence down the western slope of the continent to the Pacific Ocean.

The Mackenzie River, rivaling in its proportions the Upper Mississippi, breaks the apex of this triangle, escaping through the Rocky Mountains to the Arctic Sea; while the Saskatchewan and other rivers of the southern British territory dilate into great lakes at the western base of the Laurentian axis, through which they then escape to Hudson Bay.

The Laurentian axis of metamorphic rocks with its fringe of Silurian strata may be considered as stretching from Western Canada to the Arctic Ocean, near the mouth of the Coppermine River, in a N.W. direction; but it sends off a spur, which encircles the western shore of Lake Superior, and loses itself under the prairies of the State of Minesota.

Lake Superior and Lake Winnipeg, according to the surveys of the Canadian Expedition, have nearly the same altitude of 600 feet above the sea, while the rocky district that separates them has double that elevation, or 1300 feet, above the sea; but this is in many places increased to 1600 feet by the deposits of drift that will be hereafter described.

The highest point of the great plateau that is in British territory is to be found when, at the base of the Rocky Mountains, that chain is intersected by the 49th parallel of latitude, where it is elevated 4300 feet above the sea. If followed into the United States to the south, it is found to reach a still greater elevation along the base of the mountains, until it merges with the great table-land of Mexico, which has an altitude of 6000 feet. From the above point of intersection to the nearest point of the Laurentian axis, which is a line from near the source of Belly River in a N.E. direction to Cumberland House on the Saskatchewan, the distance in an air-line is over 500 miles, and the difference of elevation of these two points gives a mean slope of 6 feet in the mile. The general level of the eastern base of the Rocky Mountains also declines rapidly to the north; for in latitude 51° 9′, at where the Bow River emerges on the plains, the elevation is 3900 feet, and at where the Athabasca, the most southern tributary of the Mackenzie, leaves the chain in latitude 53° 12′, it is only 3300 feet above the sea*.

The slope of this plateau is, however, far from being uniform, but is broken by steppes which have been formed by the erosion of the surface of the country, and which indicate different grades in the elevation of the continent during later epochs. These steppes are boldly marked, sometimes increasing the altitude of the prairies,

* As the Rocky Mountains are cut through by valleys almost to the depth of the plateau on which they stand, this depression of the chain towards the north has a remarkable influence on the climate in some localities, especially mitigating the severity of the spring months by admitting the influence of the mild climate of the western sea-bord at a time when the eastern part of the continent in the neighbourhood of the great lakes is still icebound.

as the traveller follows a westerly course, by an abrupt rise amounting to 600 feet. They have a very irregular outline, and are cut through by the river in many cases, so as to form isolated masses of broken table-land. (See general section: Sections Nos. 1 & 2, Pl. XIII.)

The Rocky Mountains forming the western limits of the great plateau rise from it very abruptly, the eastern ranges often presenting sheer cliffs 2000 to 3000 feet in height. These are, however, cut by transverse valleys into which the superficial deposits of the prairies penetrate, and have been preserved, more or less perfectly, as terraces in the mountain-valleys.

The mountains formed of broken plications of strata, as will be afterwards described, are disposed in parallel groups, the great valleys in the length of the chain generally occupying anticlinal fractures. The flexures have been more perfectly developed in the eastern part of the chain than towards the central parts, where the mountains have a massive cubical aspect, the strata having been fractured and upheaved rather than bent by disturbing agencies. This is owing, no doubt, to the mineral composition of the strata, and not to any modification of the disturbing force; for, as the western slope is descended, slaty rocks are met with, which again present perfect flexures. The mean altitude of the Rocky Mountains between latitude 49° and 53° is about 12,000 feet above the sea, but there is a very singular absence of marked peaks. The chain culminates in latitude 52°, where the mountains are very massive and are traversed by profound valleys, the heads of which are occupied by glaciers.

From the Rocky Mountains to the Pacific Ocean the country is extremely rugged, resembling similar Silurian and metamorphic regions in other parts of the world. It forms a great trough, bounded to the west by the Cascade range of mountains, which closely hugs the Pacific coast in this latitude. This range, which is only rarely broken by valleys, and those of comparatively recent date, runs like a wall 4000 to 5000 feet above the sea-level. At intervals there occur great conical mountains, such as Mount Hood, Mount Baker, and others, which rise to 10,000 or 12,000 feet, and from their isolation, being perfectly unconnected, except by the lower range, they present a very grand appearance when viewed from the coast. Owing to the great fall of the rivers, the narrow valleys, and the rapid erosion having continually carried on the rearrangement of the superficial deposits, the grades in the elevation of the continent cannot be so well discerned on the western slope as on the eastern, although these deposits are found to be greatly developed.

After this brief sketch of the physical features of the country, I now proceed to describe the different strata, reversing the order of their deposition.

SUPERFICIAL DEPOSITS.

These are very extensively developed in every part of the region explored; and their classification involves very interesting conclusions respecting the changes of level of the continent, both posterior and anterior to the great northern drift.

Judging from the altitudes at which erratics are found to be dispersed, the continent must have been depressed at that period beneath a sea in direct connexion with the Arctic Ocean to the depth of nearly 3000 feet; and since then, during its gradual emergence, this region of North America has received its present form of surface by denudation,—first, as effected on seacoast-lines, and latterly by the coast-lines of great inland lakes, which, it will be shown, though still existing, were previously of much greater dimensions.

The superficial deposits during and posterior to the Drift are so different on the opposite sides of the Rocky Mountains that they must be treated of separately, whilst those anterior to that epoch will be found to have a common character.

Terraces of the Lake Superior Basin.—In ascending the Kaministoquoia River for a considerable distance above the Kakabeka Falls, the country is covered by a deposit of red marl-earth which forms the high terraces of the river. Thus opposite to the mouth of White Fish River there are three distinct terrace-levels of 20, 60, and 90 feet. At some distance back from the river still higher terraces occur, belonging to this class of deposits, which must be considered as of more recent age than the true drift. Sir William Logan describes one at the height of 331 feet above Lake Superior. The great deposits of sand and gravel which rest on the highest levels of the axis, and are first met with at Dog Portage, belong, I think, to the period of the Drift, and will be referred to in the next group.

Superficial Deposits of the Central Plateau.—The steppes of this great slope may be naturally divided into three groups having different ages and circumstances of deposition, and boldly marking three distinct *Prairie-levels*. (See Sect. No. 2, Pl. XIII.) To the most recent of these belong the low prairies which surround Lake Winnipeg and the lakes of that group, including the marshy country to the west of Manitoba Lake. This forms the *First Prairie-level*. In the vicinity of the Red River Settlement, its composition is of argillaceous marl, with a deficiency of sandy matter, and it is invariably stratified in thin layers. Underlying this at various depths from the surface, is a bed of stiff clay, which forms the immediate margin of the river at many places. The upper layers of this deposit contain leaves and fragments of wood and reeds, and the whole is undoubtedly a fresh-water deposit, indicating a time when the Winnipeg group of lakes covered a much more extended area than at present, the gradual deepening of the rocky channels through the eastern axis having increased the drainage in modern times.

The surface of this deposit is about 75 to 100 feet above Lake Winnipeg, but it slopes gradually from the west, and at Pembina Mount, near St. Joseph, is at least 100 feet higher. To the east of Red River, in descending the Winnipeg River, two well-marked levels were observed which belong to the group of extended lake-deposits. Thus below the Seven Portages that river flows through a smooth channel, and the banks are composed of a white marl-earth; the river being at first only slightly depressed, but soon from its rapid descent, while the level of the deposit remains the same, the

banks become high. At the Rat Portage, this terrace, which is 150 feet above Lake Winnipeg, retires from the river on each side, and is replaced by another at an altitude of only 75 feet, through a cutting in which the river flows to its mouth at Fort Alexander. This ancient lake-bottom extends south of the 49th parallel into the American State of Minnesota, and everywhere presents a rich level prairie, only broken by slight gravel-ridges which have formed shoals in the ancient lake, or by patches of the magnesian limestone beds which crop out into the plain, such as at the Stony Hills, east of Fort Garry, which must have been a rocky island at one time.

The banks of the lower part of Rainy River are composed of rich alluvial deposit of a light-grey colour, containing a large proportion of white sand. It is distinctly stratified, and has without doubt been formed by an extension of the Lake of the Woods back towards Rainy Lake. In the upper part of Rainy River, the banks are high and terraced, and boulders show that at this level there is also a deposit of true Drift.

At Pembina Mountain, the eastern limit of the *Second Prairie-level* forms an escarpment measuring 250 feet above the plain at its base. From the point where it crosses the 49th parallel, it sweeps to the north-west and assumes a more gentle slope, being broken up into three or four subsidiary terraces. It then meets the Assineboine River near the mouth of the Souri, and is continued to the north by the high grounds that lie to the west of Manitoba Lake from Riding Mount to the Basquia Hills, which, however, rise to the full height of the level—that is, to 1600 feet above the sea. Below Fort à la Corne the banks of the Saskatchewan are described as suddenly becoming reduced from the height of several hundred feet to a slight elevation above the river, showing that it is at that place where the eastern limit of this level meets that river. The prairies of the Upper Assineboine, the Qu'appelle River, and those along the Saskatchewan, from Fort à la Corne to the elbow on the south branch, and also up as far as the longitude of Fort Pitt on the north branch, all belong to this level, which also extends to the base of the Great Missouri Côteau. The mineral composition of the superficial deposits of the Second great Prairie-level is very different from that of the first. Sand is the predominating ingredient. Thus at St. Joseph, where the banks of the Pembina River present a fine section of it to its base, the material is a coarse red sand, with gravel and boulders. There are no signs of stratification in any part of this deposit as seen at Pembina Mount, but further west, where it assumes a light-grey colour, and contains a considerable quantity of lime, it is imperfectly bedded. Near Fort Ellice, and at many other parts of the district to the south and west of that place, this deposit is formed wholly of fragments of the underlying Cretaceous shales. At Long River, Forked Creek, and many other places, this deposit was observed to form only a very thin coating to the Cretaceous rocks. Notwithstanding that the prairies of this level are often cut to a great depth by the rivers and

creeks, very little can be learnt of its nature at different points, as slides in the banks of the gulleys are rarely seen. At Fort Ellice the valley of the Assineboine is 240 feet deep, and about 100 feet of that is composed of this drift-deposit resting on the Cretaceous beds. In the Qu'appelle Valley, near the Mission, a slide exposed the deposits beneath the plane to the depth of 250 feet, showing it to be composed of stiff sandy clay of light-red colour, with patches of blue clay and gravelly beds. On the whole, the character of this level, as far as regards its mineral composition, is variable and local. Boulders are tolerably plentiful all over its surface, but occur in greatest quantity on the sides and summits of ridges and mounds, which rise in groups to the height of from 50 to 80 feet. Immense outliers of a still higher level occur, attesting the immense denudation which has taken place; these generally rise from 1400 to 1600 feet above the sea, which latter is the height of this level at the base of the Grand Côteau, Eagle Hills, and Thickwood Hills, all of which form the eastern limit of the next great steppe. (See fig. 1.)

Fig. 1.—*Section 16 miles above the Elbow of the South Saskatchewan, showing the junction of the Drift and the Cretaceous clays at the base of the Third Prairie-level.*

a. Drift. *b.* Septaria-clays (Upper Cretaceous).

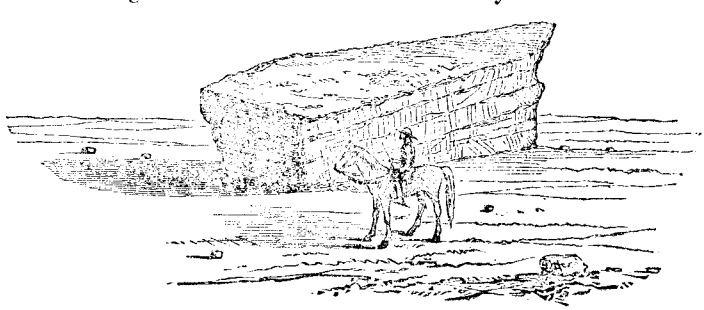
These outlying patches occur along two lines parallel to the general contour of Lake Winnipeg and that of the next higher level to the west, and were doubtless continuous ridges until cut through by the different river-valleys. Thus overhanging the lakes, we have the Pas, Porcupine, Duck, and Riding Mounts; and to the west, a line of which the Touchwood Hills, Moose and Turtle Mountains form the principal points. These have all a common character, rising gently to an ill-defined table-land from the west; while their eastern aspect is extremely rugged, presenting irregularly deposed ridges of coarse sandy drift highly charged with boulders. This steep escarpment is generally densely wooded, and encloses numbers of small lakes.

The eastern limit of the *Third great Prairie*-level is met with at the Grand Côteau, Eagle Hills, and Thickwood Hills, and is only cut through by the channels of the north and south branches of the Saskatchewan; while all the other rivers of the eastern plains, such as the Souri, Assineboine, Qu'appelle, &c., have their sources short of it. I have stated the prairie at the base of this *third level* to have an elevation of 1600 feet above the sea, and a depression of the continent to this extent would be sufficient to submerge the eastern Laurentine axis between Lake Winnipeg and Hudson Bay, or at least to convert it into a mere chain of islands. The eastern coast-

line would then leave the Rocky Mountains in latitude 56° N., near Peace River, and would follow what is now the water-shed between the Saskatchewan and the rivers more to the north, till it reached the 107th of longitude. From this point the Thickwood Hills, Eagle Hills, and Thunder-breeding Hills would form the headlands of a great bay into which poured the waters of the two Saskatchewans, at that time independent rivers debouching where they now make the acute bends known as their "Elbows". The coast-line was then continued to the south-east, forming the *côteau* that dips between the Missouri and St. Peter's Rivers. As seen from a distance when travelling in the low plains, this great steppe appears as a range of blue hills with a smooth undulating outline. On approaching it a gentle ascent is accomplished for many miles, after which an abrupt rise of from 400 to 600 feet has to be effected, generally in from 4 to 6 miles. The surface of the slope is extremely rugged, and has evidently been worn into pot-holes, ridges, and conical mounds by the action of water on the soft clay strata of the Cretaceous group. Everywhere the slope is thickly strewn with boulders, all derived from the Laurentian chain to the east, or from the Bird's-eye Limestone which rests on the western flank of that axis.

Near the elbow of the North Saskatchewan a remarkable group of boulders of this kind of limestone, of enormous size, crosses the country in a line parallel with the *côteau* to the west. This line has been observed at points 30 and 40 miles apart. They occur as great angular masses, consisting of several of the beds of limestone, the coherence of which being very slight proves that they must have been stranded without any great violence. One of these masses contains over 3000 cubic feet of stone, and rests on the plain obliquely with its south-western angle buried in the soil (see sketch, fig. 2).

Fig. 2.—*Boulder on the Plains south of Carlton.*



More to the west than this is a line of sand-hills, which has evidently marked a coast-line, although their original position may now be much altered, since they are still wind-blown as during their first production. They have a clear relation to the ancient level, and are found at the same altitude over such a stretch of country, always at a little distance from the base of the escarpment, that there

can be no question as to their origin. Similar sand-hills were observed on the Souri River at the base of the Second Prairie-level, which must have been formed on the shore of the extended lake.

The resemblance which the plains along the base of this great steppe bear to the shore of Hudson Bay at the present time may be judged of from the description given by Sir J. Richardson, who says, "The western shore of Hudson Bay between latitude 56° and 58° is flat, and the depth of the sea decreases very gradually on approaching them. In seven fathoms of water the tops of the trees are just visible from a ship's deck. Large boulder-stones strew the beach, and form shoals even at the distance of five miles from the shore, which are very hazardous to boats." In proceeding up the river from this coast, he says that after a tract of level country "the banks" (consisting, he before mentions, of drift-clay and boulders) "rise from a very narrow river-channel to an elevation of very nearly 200 feet. Their outline is broken into conical eminences by short ravines, which open into the river at right angles. These banks have exactly the same form and constituent parts as those which occur on the confines of Lake Winnipeg and the Saskatchewan." As he made the latter remark in allusion to the nature of the underlying rocks at the two localities without reference to the drift, it is all the more valuable for the purpose of proving this similarity, which is so striking between the present state of the coast of Hudson Bay and the ancient coast-line along the base of the Third Prairie-level. In the rugged district of this steppe there are enclosed numerous lakes, some of great size, and all, without exception, more or less impregnated with salts, of which sulphate of soda is the predominating ingredient. In autumn after the dry summer, these lakes are fringed with crystals, and the soil in many places is covered with a white efflorescence. Whether these salts are derived from the superficial deposits of the ancient coast-line or from the Cretaceous clays, I am unable to say; but the position of the salt-lakes, generally at the same altitude, inclines me to the former opinion.

The Laurentian axis is covered with a great deposit of drift, consisting of coarse red sand, with many large and small boulders. This deposit forms a flat swampy plain, well wooded towards the west, but towards its eastern margin, as at Cold Water Lake, worn into deep dry gulleys and round pot-holes without any exit. The thickness of this deposit is from 200 to 300 feet, and the highest point of it is about 900 feet above Lake Superior, or on a level with the plains near Carlton. Glacial scratchings were distinctly seen at many parts of the axis. The direction is generally north and south. Hardly a surface in the granitic tracts did not present distinct scratches. They were seldom, however, to be observed on southern exposures of rock-surfaces if these sloped much; but the more surfaces with northern exposures sloped, the better they seemed to be marked.

As will be seen from section No. 2. Pl. XIII., in rising to the surface of the third steppe we have the plains composed of the Cretaceous strata with only a very thin coating of Drift, which has always a local

mineral composition, corresponding with that of the underlying strata, without admixture of materials carried from a distance further than a sprinkling of erratic blocks, of small size, and only to be found crowded on favourable spots.

These consist almost entirely entirely of fragments of metamorphic rocks, limestone being very rare.

I have not remarked the ordinary erratics at a greater altitude than 3000 feet; but at 3700 feet above the sea and 50 miles from the Rocky Mountains, there occurs a very extraordinary group of blocks of granite, resting on a high plateau formed of sandstone strata. These blocks are of great size, one having been estimated to weigh 250 tons. Although lying in a line miles apart, they seem to consist of the same rock—viz. a mixture of quartz and red felspar, the latter predominating, with only faint traces of mica disseminated in very minute flakes. They present smooth surfaces, although in general they are rhomboidal in form. Some of them are cracked into several pieces, which are quite detached, but are evidently parts of the same block*.

If these blocks were derived from the granitic belt to the east, as I believe all the erratics of the prairies have been, they must have travelled at least 400 miles. From the fact, however, that they are beyond the western verge of the Drift, and that the boulders were found, as a rule, to diminish in size in that direction, it may be that the presence of these blocks is due to very different agencies,—different, at least, in the time of their occurrence. No granite was observed on the east flank of the Rocky Mountains within British territory, but the Trois Butes, south of the 49th parallel, are said to be composed of granite, and also the Black Hills; but both of those localities are much to the south of where those blocks occur.

The surfaces of the higher plains are in some localities traversed by profound rents, resembling the valleys of great rivers, but which, after running for several miles, are generally found to be closed at both ends. They are often occupied by deep lakes of salt water, depressed 200 feet to 300 feet below the plain, and from 500 yards to a mile in width. The great *coulées* in the neighbourhood of the Ear Hills, south of Battle River, are the best examples of these; but they are found in many other localities. It is difficult to conceive that they are due to erosion alone†.

Before leaving the superficial deposits of the prairie-country, it is necessary to notice the great river-valleys which traverse it, and

* For mention of a similar phenomenon, see Hooker's 'Himalayan Journals,' vol. i. p. 201.

† The ravines mentioned by Sir Charles Lyell in his Second Journey in the United States, p. 25. vol. ii., as occurring in the cretaceous and tertiary strata of Georgia, seem to be very similar to them. He says, that when the woods are cleared from the country, the sun, acting on the unprotected surface of the argillaceous strata, produces cracks that are soon enlarged to great gulleys by the torrents of rain that fall. We may suppose that on the Saskatchewan, where there is only a small quantity of rain, the winter's frost effects the same result, but with this difference, that the successive landslips, remaining unmoved, at last form such a gentle slope that vegetation can retain its hold, so that the rent is finally represented by a symmetrical valley.

which all point to a time when the rivers exercised a more powerful influence than now; as even small streams, such as Battle River, flow through valleys from 150 to 250 feet deep, which have been partially refilled with stratified deposits. The sides of these valleys are in general as regular and formal as those of a railway-cutting, excepting where the nature of the strata causes frequent slides, or harder beds give rise to a cliff-structure. The flat alluvial bottoms of these valleys are often four or five times the width of the river which winds through them, and which is hemmed in by secondary banks 30 to 40 feet high. The silt and alluvium are in general regularly stratified, and almost every river-point contains one or more lagoons, showing the frequent, though slow, change in the river-channel.

Terrace-deposits of the Mountains.—At the distance of 90 miles from the Rocky Mountains, the valleys of the rivers flowing to the east commence to exhibit terraces composed of rounded fragments of quartzite and limestone, such as would form the rounded shingle on a rocky shore. At the Rocky Mountain House, where these terraces first attracted my attention in the winter of 1857-58, the North Saskatchewan has excavated a valley in the Cretaceous strata, which varies greatly in its width, sometimes being hemmed in by perpendicular cliffs of sandstone, and sometimes sloping gently back to the elevated country on either hand where the strata had been less able to resist the erosion.

In this valley there are three terraces extensively developed at 20, 60, and 110 feet above the water-level*. Until we approach close to the mountains these terrace-deposits are confined to the valleys of the larger streams, but gradually they spread out, and at last cover the whole country along the base of the mountains, filling up the hollows and valleys of the outer ranges to the depth of several hundred feet. This feature was observed at every point where we approached the mountains from the east, from the 49th parallel northwards, and indeed was even better marked on the Athabasca River than on any of those further south. Judging from the accounts of American explorers, these terraces extend along the base of the Rocky Mountains all the way south to Mexico.

One hundred miles east of the mountains, in latitude 49° 30′ N., shingle-beds are found to cap the Cyprés Hills, which have an altitude above the sea of 3800 feet, or nearly the same as that of the base of the Rocky Mountains. The Cyprés Hills are nothing more than the western extremity of the great Missouri *côteau*, which, curiously enough, here presents an escarpment to the west, and is separated from the mountains by a tract of flat arid country of the above width. This *côteau* is composed of Cretaceous and Tertiary strata, which have remained as a dividing ridge, from the denudation having acted to the north and south of the line which it marks. It is on the west and south exposures of these hills that the shingle occurs, formed into terraces like those along the mountains.

These are not to be classed, however, with the river-terraces, which

* These are roughly introduced in fig. 7. p. 424.

are of much more recent formation, having been derived from the deposits along the base of the mountains *.

This may not only be inferred from their relative position, but also from the composition of the terraces themselves; for, although the pebbles are the same in all, those in the valley-terraces are well cleaned and mixed with sand, while in the terraces along the mountains and on the Cyprés Hills they are often encrusted with white calcareous matter. This sometimes increases so as to form a perfect cement, so hard as to allow of the fracture of the pebbles before that of the matrix, just as is seen in some ancient conglomerates †.

On approaching the Rocky Mountains the extreme regularity with which these deposits have been terraced by retiring waters at once attracts attention. At the place where Belly River leaves the mountains, in latitude 49° 34′ N., Capt. Blakiston measured three of these terraces, and found that they were elevated 61, 152, and 202 feet above the river-level, which at that point, according to his measurement, is 4024 feet above the sea. He describes them as being "very marked, appearing as a succession of steps from the level of the river to the plain above, often in sight for miles and running horizontally. The tread of the step is of variable width, but the rise is nearly always abrupt and well marked." From the regularity of these embankment-like terraces in the valley of one river, he named it Railway River (Further Papers, Palliser's Expedition, 1860, p. 68).

On Bow River they are also well marked, and there I measured four at the altitudes above the river-level of 30, 140, 170, and 240 feet, and traces of one still higher at 350 feet. The valley of Bow River within the mountains is narrow and tortuous for the first twelve miles, and in this part of its course the terraces are hardly preserved. Above this point, where it occupies one of the expanded horizontal valleys conforming to the strike of the strata, they are again enormously developed. Even on gaining the Vermilion Pass the only steep climb is at first, up the face of these terraces for 150 feet; and then a gentle slope leads to the height of land.

The valley of the North Saskatchewan is much wider and more direct within the Rocky Mountains; and there we have not only these terraces remarkably developed, but also their mineral composition much altered, partaking of what will be found to be their character on the western slope of the mountains. At a similar place, with respect to the mountains, to where the terraces were measured on Bow River, four were estimated to have an altitude of 25, 70, 180, and 300 feet above the North Saskatchewan. The shingle, cemented into a hard conglomerate, was here seen to rest on the edges of the contorted strata of grit and shale with thin

* In latitude 42° at the base of the Rocky Mountains near Fort Laramie, Hayden describes similar "deposits of coarse conglomerate, 50 to 150 feet in thickness, formed since the scooping out of the present river-valleys."—Proc. Acad. Nat. Sci. 1858.

† Darwin says of the shingle-formation of Patagonia, "The pebbles are imbedded in a white, gritty, calcareous matrix very like mortar, sometimes merely covering with a whitewash the separate stones, and sometimes forming the greater part of the mass."—Geol. of S. America, p. 19.

seams of coal. Within the mountains the terraces expand so as to form level prairies along the North Saskatchewan, of which the Kootanie Plain is the principal. It is many miles in extent and composed of shingle and incoherent sand, the widest terrace being 100 feet above the river. The river is, however, skirted by terraces at still higher levels, especially on the south or right side of the valley. Above Pine Point the calcareous matter of these terrace-deposits so increases as to replace altogether the pebbles, and they are often composed of fine gritty calcareous mud of glistening whiteness. If followed into the higher valleys, they become confused with the detritus of ancient glacier-moraines, which, however, are easily distinguished by the angular blocks which they contain.

On the Athabasca River, at fifteen miles from the mountains in a direct line, the terraces were found at 15, 100, 210, and 370 feet above the river-level. Within the mountains, this valley, which is more dilated than even that of the North Saskatchewan, has also the terraces better developed than I have elsewhere observed them on the east side of the chain. The river moreover dilates into extensive lakes at different points of its course, and there the rearrangement of the material of the terraces is seen to be going on; the water separating the calcareous mud from the pebbles, while the winds, which are extremely violent in this valley, sift out the fine sand and pile it in tracts of sand-dunes which cover large areas.

The terraces may be considered as ranging on the east side of the Rocky Mountains from 3500 to 4500 feet above the sea. Wherever they prevail they support a growth of a peculiar sturdy pine which, in common with the Banksian Pine, is known to the Hudson Bay Company's hunters as the Cyprés *.

Often the surface of a terrace is quite free from timber, the trees being easily thrown out of the loose gravelly soil, and then it is generally clothed with "bunch-grass†," which at once catches the eye as different from the grasses of the eastern plains. The country occupied by the terraces is easily passed through, as the forests are there free from underwood, and the only obstacle to the traveller arises from his having so often to make a steep descent to the base of the deposit, which is cut through by every little stream, and then to climb again the opposite bank. When passing along the side of a valley, the numerous cross gulleys due to this cause would render the construction of a road a very difficult matter, although nothing could be firmer or more level than the surfaces of the terraces themselves. This remark applies equally to the valleys on the west side of the Rocky Mountains, where the terrace-deposits have a much greater development.

Terraces of the Western Slope.—All the valleys between the Rocky Mountains and the Pacific coast lower than 4000 feet above the sea

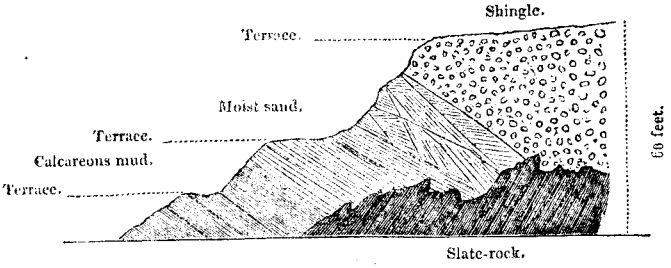
* This pine is allied to the *Pinus inops* of the Atlantic bord and to the *P. contorta* of the Pacific, and yet has distinctive characters from either. It has been proposed to call it *Pinus Saskatchewensis*, Hooker.

† *Festucæ* of various species. The grass on the eastern plains consists of varieties of *Chondrosium* (Blodget's 'Climatology of the United States,' p. 451).

are found to be more or less occupied by deposits which are terraced with greater regularity.

On descending the western slope, these deposits were first observed in the lower part of the valley of Vermilion River, where they are formed of the same glistening, white, calcareous mud that was seen in the valley of the North Saskatchewan; but it is in the wide valleys of the Kootanie and Upper Columbia Rivers that these terraces are best developed in the Rocky Mountains. These rivers run in opposite directions through the same great valley which lies parallel with the mountain-axis for nearly 250 miles, and which throughout is skirted by terraces forming a succession of platforms, often rising to 600 feet above the river. These extend into the side-valleys, preserving their horizontal character, but their composition is often changed. At various points these deposits were seen to be distinctly stratified, and in some cases they must have been disturbed between the time of their formation and that of their being finally moulded into terraces. Thus where the Kicking-horse River joins the Columbia, and where both valleys present perfect terraces at five different levels, the highest, forming a wide shelf 540 feet above the river, the appearance which is exhibited in fig. 3 was observed, where the stream has worn away the bank.

Fig. 3.—*Terraces in the Valley of Kicking-horse River, Rocky Mountains.*



The erosion of these deposits, and the production of steep and quickly succeeding terraces (both being processes which may have been simultaneously effected on successive shore-lines either of the sea or of inland lakes) have been much more perfect in the valley of Columbia, as far south as latitude 51°, than in the remainder of the Columbia valley, which extends for a degree further to the south, or throughout that portion of the same great trough which is occupied by the Kootanie River; for there the deposits remain comparatively undisturbed, and form great stretches of prairie, only cut through by a narrow but deep channel for the river. The change of appearance in the valley from this cause is very abrupt and striking. North of latitude 51° the terrace-steps succeed one another rapidly, with the *tread*, or horizontal surface of the step, narrow and furrowed; and the traveller's progress is here impeded by the dense growth of forest of a northern type, consisting of varie-

ties of Spruce-fir for the most part, with dense underwood; but on passing south of the slight bend of the Columbia, the *tread* of the terrace-steps commences to expand into wide level plains, dotted with a forest of the sturdy *Pinus ponderosa* or the gigantic *Larix occidentalis*, both of which are trees that find their maximum in Southern Oregon. The outlines of the terraces still preserve the same extreme formality and steepness of slope, but on their level surface a rider can gallop in almost any direction, so free is the forest from underwood. Sometimes the trees are entirely wanting, leaving great tracts of open plain embosomed in the mountains, forming the camping-grounds of the Kootanie and Flat-head Indians, on which they raise the large bands of horses for which they are famous amongst all other Indians, the dry soil and nutritious bunch-grass producing a breed of superior hardihood and swiftness.

In descending the Kootanie River from the Tobaco Plains * to Colvile the country is rugged in the extreme, and these terraces are met with wherever they have been sheltered from recent erosion in valleys of unusual width or in recesses of the more narrow ones. On reaching the belt of country where schistose and metamorphic rocks prevail, the pebbles are often composed of greenstone, quartz, and the other vein-rocks of the strata which they overlie. On reaching the lower part of the country near Colvile, the terraces are still found in all the valleys, not only at moderate elevations but also high up in the mountains. Thus the Columbia at Fort Colvile, in latitude 48° 34′, is 1000 feet above the sea, and terrace-deposits were observed on the sides of the valley at least 1200 feet above the river-level.

The great Columbian Desert and the Spokane Plain are both covered with the same deposits of shingle, resting, in the former case, on the great lava-flocs, and, in the latter, on granite and metamorphic rocks. The Spokane Plain, which is of comparatively limited extent, has its margin beautifully terraced, repeating on a grand scale the same phenomena as may be observed on the shore-line of a shallow lake after the summer-drought. At old Walla Walla, where the Columbia River passes from a wide and flat sandy desert to break through the profound rocky *cañon* of the Cascade Range, the whole country is covered with light blown sand, which renders it almost uninhabitable, being swept in clouds by the high gales that constantly blow either up or down the river through this wonderful chasm. Here in an ancient lake-bottom have been found the remains of a *Mastodon* by some American explorers.

To the west of the Cascade range of mountains along the Pacific coast, terraces of shingle prevail as in the interior. Also on Vancouver Island they were observed near Nanaimo. Near Fraser River and Puget Sound they are very well marked, and at the latter place occur the "Mound-prairies," which, however, I only know of by report. These are level surfaces of terraces free from forest, and covered with lines of conical mounds, 10 to 20 feet high, said to be formed of

* The term "Tobaco Plain" should properly be only applied to a little plot near the Kootanie Trading Post, but we have thought it advisable to extend the name to all the large plains along the Kootanie River near lat. 49° N.

boulders piled on one another and resting on the surface of the shingle.

Terraces in California.—Before leaving these shingle-deposits, which are so largely distributed throughout the mountain-valleys of British North America, I may mention that in California I found these terraces ranging on the western slope of the Sierra Nevada, at least to the height of 3000 feet, and there they are extensively worked by the hydraulic method for the sake of the gold they contain. At Nevada City, and also on the Yuba River, I saw deposits of this shingle-conglomerate, 200 and 300 feet in thickness, actually being washed off from the face of the country by this powerful means, which consists in delivering water under great pressure against the face of the cliff, from nozzles like those of a fire-engine. The supply of water for this purpose is in the hands of companies separate from those that conduct the mining, as it is often brought through tunnels and over high-level aqueducts from remote and uninhabited regions. The particles of gold are disseminated throughout the whole deposit, but the richest washings are from its base, where a pink pipe-clay, technically known as "pay-dirt," rests on the "bed-rock." The whole water, with the material washed out of the cliff, is directed through long troughs called "flumes," which are constructed of wood, like mill-leads, often continuously for six or seven miles. The large stones are thrown out, as they pass, by men with shovels, to save the wear on the bottom of the "flume," while the finer material is carried on by the rush of water, and passes over frequent cross bars called "ripples," where a little mercury is placed to entrap the gold by amalgamation. At Nevada City, where the coating of shingle-deposit has thus been cleared from the surface of the coarse-grained and soft granite which underlies it, gigantic masses were exposed on what had once been the rugged shore of an inlet, just as may be seen on a waterworn coast of the same material at the present day. In California fragments of wood are found throughout the shingle in abundance, often carbonized, but in general silicified into a substance exactly resembling asbestos. In the sand and conglomerate of the Kootanie Valley I found fragments of wood of similar appearance.

As my observations in California should not properly be introduced in this paper, I shall leave them for another opportunity, the object of my having mentioned them being to point out the great similarity between the superficial deposits of the great gold-country and those within the British territory further north, which encourages me to assert that the whole country up to the Kootanie River and the base of the Rocky Mountains, wherever the ancient terraces prevail resting on Silurian or metamorphic rocks, will be found to be auriferous. In my party in 1859 I had an expert "washer" who had been at the Californian mines; and he frequently got "colour," as a faint trace of gold is termed, by merely washing the gravel from the beds of the streams, without any regular "prospecting" or "digging." The discovery of what are among the richest "pan-diggings" on the Pacific coast in the Schimilkomeen Valley, and the existence of

gold-mines worked since 1855 on Clark's Fork, half a mile north of the boundary-line where it meets the Columbian River, prove that the belt of auriferous country in California and Oregon is continuous with that of Fraser River; and there is no reason to doubt that in a short time the rugged and unexplored country which forms a triangular region north of the boundary-line, and is drained by the waters of the Upper Columbia and Kootanie Rivers will be overrun by prospectors, and then by active gold-miners, just as the western part of British Columbia has been within the last few years *.

Age of the Terrace-deposits.—The evidence we have respecting the age of the terrace-accumulations is very imperfect. There can be no doubt that those occupying the valleys of the Rocky Mountains, being furthest from the coast and at the greatest elevation, are the most ancient, and that from the time of their deposit till now the rearrangement of the same materials has been carried on during the gradual uprising of the continent.

The shores of the intricate channels and inlets on the Pacific coast of British North America, if elevated from the sea, would present but slight difference from sides of the narrow valleys in the Rocky Mountains at an altitude of 3500 feet. Whether the continent was ever in later times depressed to that extent in the mass, or whether the central upheaval has been much greater than that along its margin, is a consideration of great importance, and could perhaps be settled by ascertaining to what altitude the terraces can be traced on the Cascade Mountains.

The existence of marine Tertiaries along the coast, supposed to be of the same age as those in the eastern prairies, and also within the Cascade Range at slightly greater elevation and sometimes overflowed by the lava from those mountains, would seem to indicate that the elevation has been very unequal; or, in other words, that the Tertiary formations along the Pacific coast have hardly been raised at all, while those in the interior are elevated several thousand feet.

On the eastern plains we have marine and other Tertiaries at an altitude of about 3000 feet above the sea, and Hayden describes them as "in all cases undisturbed, and not unfrequently resting on the upturned edges of azoic and granitic rocks†." But in the prairies these Tertiaries, along with the Cretaceous strata on which they generally repose, have been enormously denuded, and are found merely as outlying patches forming the tops of hills. It must have been during the period when this denudation of the eastern plains accompanied the gradual emergence of the continent, but acting with very different results on the rocky sea-bottom and successive ranges of iron-bound coast presented by the western slope, that these immense deposits of shingle were formed and moulded into terraces‡.

* I have just heard that some Americans have discovered that there is gold deposited by the Saskatchewan at the Rocky Mountain House. If so, it must be washed out of the shingle-terraces along the eastern base of the mountains.—Aug. 1, 1861.

† Proc. Acad. Nat. Sci. 1858, p. 17.

‡ In many cases there is no doubt that the terrace-arrangement has been

But if this reasoning is to apply to the most ancient of those accumulations, and so place them as more recent than the latest Tertiary times, then there must have been a slight depression prior to the steady and gradual elevation of the continent that has continued ever since. Moreover, unless this depression was local and confined to the mountain-region, how are we to account for the absence of Post-tertiary formations over the high-lying Tertiaries of the plains in sufficient quantity to have allowed time for the production of such a gigantic formation of waterworn stones?

On the other hand it is possible that their production may have commenced in Tertiary times, so that they are almost coeval with the great lignite-basin of the Missouri, which is an estuarine deposit resting, according to Hayden, quite conformably on his Upper Cretaceous beds.

He also describes his Titanotherium-bed, the lowest of the White River Tertiary basin, which has yielded so many forms of chelonian and mammalian remains, as likewise resting without a break of conformity on the Upper Cretaceous*. Thus if this latter suggestion respecting the age of the most ancient of the terraces be correct, they must have been formed in the straits and inlets of an archipelago or rocky reef lying to the west of a flat Cretaceous continent, in which were estuaries and lagoons choking with rank vegetation, and large lakes, which gradually filled up, burying the remains of the gigantic turtles and extinct forms of mammals.

In the Gulf of Georgia there are beds of conglomerate and coarse sandstone overlying the Cretaceous strata to all appearance, and which, I have thought, may perhaps correspond to the more ancient of the mountain-terraces to which they bear a great mineral resemblance, excepting that those in the Gulf of Georgia have been much disturbed, so that they are harder and their bedding is better marked. The difference is, however, not greater than we should expect, if we consider the one group to have been placidly raised to a great altitude, while on the other the force has been expended in producing plications and faults.

Drift of Pacific Coast.—The glacial markings on the metamorphic rocks of Vancouver Island are better displayed than I have elsewhere seen them. Every surface near Victoria that is either naturally exposed, or from which the soil has been removed, exhibits deep parallel furrows, generally with a N.E. trend. They are also seen on the main land at the entrance to Puget Sound quite as distinctly. Erratics are distributed all along the Pacific coast, at least as far south as latitude 46° N., where they occur, but not very plentifully, near Vancouver and in the valley of the Willamette. They are often of great size, and on Vancouver Island are composed of a grey

given to these deposits by the shore-line-action of lakes which formerly occupied the irregularities of the surface of the country; but we can hardly suppose that the material itself, consisting of smoothly worn fragments of the hardest rocks, could have been entirely the result of the feeble erosive agencies that such lakes exercise.

* Proc. Acad. Nat. Sci. 1858, p. 19.

syenite, which Mr. Bauerman told me occurs in the Cascade Range. Often in the woods to the south of Fraser River I saw solitary boulders 6 or 8 feet high, resting apparently on the shingle-terraces which here are only 100 to 200 feet above the sea. Certainly at the Fourth Plain, five miles from Fort Vancouver, there are several large blocks, though not of the above size, that do rest on the gravel-terrace which skirts the valley of the Columbia River. On most of the islands in the San Juan Archipelago, and along the coast of Puget Sound, high sections of yellow sand and clay are exposed, forming the sea-shore. The terraces are there further inland. From this drift Mr. Bauerman procured casts of *Cardium* and *Saxicava*.

As I never observed drift or boulders within the Cascade Range, even in places elevated only 600 to 700 feet above the sea, but as all the superficial deposits in the great trough between that range and the Rocky Mountains are clearly formed from the rearranged materials of the shingle-terraces along with tufas from the Cascade Range, I conclude that the average lowest altitude of the Cascade Range, which is somewhere about 4000 feet above the sea at the present time, exceeded the depression of the continent during the glacial epoch, and presented a barrier to the causes which transported the erratics and scratched the rock-surfaces along the Pacific coast. If the Cascade Range at that time formed a promontory enclosing a gulf like the Gulf of California, it would exactly fulfil these conditions.

TERTIARIES.

The existence of Tertiary* strata, ascertained to be so by their organic remains, has only been proved at one point west from the Cyprés Hills, where Mr. Sullivan obtained *Ostrea Veleniana*, associated with a *Modiola* and a few other fossils, which Mr. Etheridge, who has named all the Cretaceous and Tertiary fossils brought home, has been unable to identify. The beds from which these fossils were obtained consisted of friable sandstones with argillaceous and calcareous concretions, with massive and irregular bedding, and often passing into incoherent pebble-conglomerate. Judging alone from mineralogical resemblance, these beds were recognized over a considerable area, but always forming high grounds in the neighbourhood of the Missouri Côteau, S.E. from the mouth of Belly River.

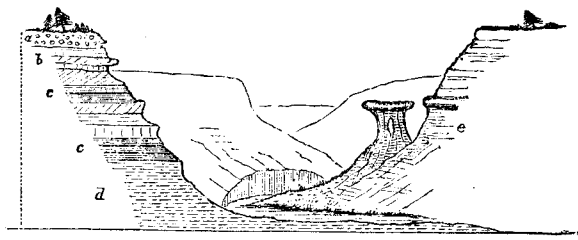
On the Souri River, seven miles north of the boundary-line, in longitude 104°, was observed what is perhaps a portion of the Missouri Tertiary lignite-basin. This locality, which is known to the half-breeds as "La Roche Percée," is well up the eastern slope of the Missouri Côteau, and within a degree of latitude of that river itself, at a point where the existence of the lignite of Tertiary age has been well ascertained.

The Souri River at this point flows through a valley with steep sides, depressed 165 feet below the surface of the plain, which at this

* Using the term in its limited signification, as including Eocene, Miocene, and Pliocene.

place is quite level, and strewn with an immense profusion of boulders, being at the base of the Third great Prairie-level. The sides of this valley are cut by numerous ravines, which only extend a short way back into the prairie, and exhibit sections of the following strata (see fig. 4):—

Fig. 4.—*La Roche Percée, in the Valley of the Souri River: a section of the Tertiary Lignite Group.*



a. Drift. *b*. Splintery limestone. *c*. Clay with lignite.
d. Coarse-grained sandstone. *e*. Concretionary sandstone.

a. Drift with boulders	4 to 7	feet.
b. Mud-stone	1	foot.
c. Incoherent sandstone, fine-grained, with hard concretions impregnated with iron, which weather concentrically	10	feet.
d Porous calcareous sinter	1	foot.
e Hard blue ironstone-shale, decomposing into deep orange-coloured splinters	2½	feet.
f Gritty limestone	2	,,
g Ash-coloured clay in thin indistinct layers, very soft, with one bed of lignite 9 inches in thickness	8	,,
h Hard blue limestone		
i Same as *g*, but with thin seams of lignite 10, 8, and 6 inches in thickness	15	,,
k. Gritty limestone	2	,,
l. Brightly coloured marls and shales, with selenite in small fragments	10	,,
m. Coarse-grained, incoherent sandstone more than	20	,,

Excepting a few fragments of plant-impressions, like stems of sedges, no fossils were obtained from these beds by which the age could be identified. They may perhaps be passage-beds, representing the highest strata of the Cretaceous era, overlain by the lignite-basin; as further south they are so disposed, and with very similar mineral characters.

The lignite does not occur in well-defined beds, but graduates into the shales on both surfaces. It is not visible until a light ashy deposit is removed from the exposed edge of the bed, which has been formed by the soft clay washing down from the strata above. The lignites are of several different varieties, some having quite the texture of compact cannel-coal of fine quality, some like the more glistening

bituminous coal, friable, and only to be obtained in small cubical fragments, while some of it can hardly be distinguished from charcoal, but all varieties have a deep purple-brown colour, which is well seen when a portion is reduced to powder. A sample of this lignite has been analysed in Dr. Percy's laboratory, at the Museum in Jermyn Street, by Mr. Charles Tookey, with the following results:—

Carbon	56·50
Hydrogen	3·65
Oxygen	18·91
Nitrogen	0·80
Sulphur	0·60
Ash	5·62
Water (hygroscopic)	13·92
	100·00

The sandstone which forms bed *c* is composed of very fine pure grains of quartz, hardly cohering; but in the upper parts of the bed there occur concretions impregnated with clay and iron, and of a reddish hue, that are comparatively hard and decompose concretionally. This irregular disintegration gives rise to a curious formation of the banks of the valley, which has rendered this locality an object of great superstition among the Indians. The lower sandstone wears away from under the hard concretions, that assume the form of compressed spheres, and sometimes long cylinders like the boilers of a steam-engine, which are left supported on pillars of the white sandstone. The gulleys which join the main valley are thus filled with grotesque forms, sometimes exactly resembling the half-buried remains of ruined edifices. The sandstone (*m*) at the base of the section is also very incoherent, but is composed of larger grains of quartz. The strata are not found in the same order and proportion throughout the valley, but yet they always appear to be horizontal. The marly shales (lettered *l*) have a considerable quantity of selenite disseminated as small crystals. La Roche Percée is in latitude 49° 6′ N., and longitude 103° 54′ W.

This formation has, without doubt, been much more extensive, and has overlain the Cretaceous beds as far north and east as the great sandy waste where the track of the Expedition crossed the Souri River in latitude 49° 30′ N., and longitude 100° 20′ W. At that place the sand-hills rise 70 and 80 feet, so pure and so feebly bound by the few plants that grow on their surface that they are constantly windblown. Under these, and cut through by the River Souri, was observed a lacustrine deposit in which one bed was composed wholly of rolled fragments of lignite, overlain by sandy marls and gravel, enclosing fragments of bones which Professor Huxley refers to the Bison; and along with these were small land- and fresh-water shells. This deposit has been found in one of the lakes, which I referred to generally as of Quaternary age when describing the superficial deposits of the prairies. The origin of this one has been

from the damming back of the water by the Blue Hills of the Souri, which are composed of hard Cretaceous shales, and through which the river of that name escapes to join the Assineboine by a narrow and profound chasm which it has gradually cut through the horizontal strata. The place where the sand-hills and the bed of lignite-pebbles is found has been the north shore of the lake, which must have been of very considerable extent.

The great valley of the South Saskatchewan where it is hemmed in closely by the Grand Côteau at its elbow opens out above that point, and at the junction of Red Deer River and Bow River in longitude 109° 30′ W., latitude 51° N., the hills retire many miles from the river, which, however, always preserves its immediate banks of from 200 to 250 feet in height. The prairies are there again covered with a waste of blown sand, which may perhaps have had a similar origin from Tertiary or Upper Cretaceous beds, which have been subjected to local denudation. The same iron-shot bands containing the shells of land Molluscs and Bison bones were there observed, but without any traces of the rolled fragments of lignite.

East from the elbow of the South Saskatchewan there is also a tract of sand-hills with quite the same feature; but there I observed masses of sandstone *in situ*, resembling the lowest beds at La Roche Percée. On the opposite site of the Qu'appelle Valley, within a few miles from where I turned, the same sandstone occurs, and there Mr. Hind found the characteristic fossils of the Upper Cretaceous group (Rep. Assineboine and Sask. Exp.).

On the North Saskatchewan, forty miles above the elbow and a little way above the Eagle Hills, on the left bank of the river, there are cliffs of a very incoherent sandstone, rising 40 to 60 feet above the water's edge, and worn into caves, which often communicate with the plain above. At the time I observed the sandstone, I took it for a local variety in the drift. If, on the other hand, it belongs to the Tertiary or the Upper Cretaceous group, it proves them to have a very singular distribution, conforming in a great measure to the present river-valleys; as on the opposite side of the river, at a little distance back, the Middle Cretaceous group rises to the height of several hundred feet.

Eight miles below the elbow of the same river, near Birch Gulley, the banks rise abruptly on either side to the height of 210 feet, when the level plain is reached at the point where the great erratic masses of limestone rest on its surface. At the base of the bank from this point, all the way down to Carlton, a distance of forty miles, springs of water escape highly charged with iron and lime, which deposit a light-yellow ochre. At the above locality the springs were seen to issue from beds of sandstone and conglomerate, with travertine containing dicotyledonous leaves.

The section is as follows:—

a. Banks of valley composed of Drift.

Coarse ferruginous sand very moist, with beds of blue- and buff-coloured clay, the whole having rounded boulders irregularly dispersed.

b. 20 feet of coarse and fine sandstone impregnated with lime, also gravel and shingle, and bed of travertine (*c*) with dicotyledonous leaves.

Ancient valley-deposit?—or underlying the Drift?

d. Present river-level with banks, 8 feet high, of silt and fine sand, forming the "points" and densely wooded islands in the channel.

I was unable to determine whether these beds have been formed, like the silt-banks of the river, at a time when it was much larger than at present, or whether they are beds cropping out from beneath the drift. They are quite consolidated, but this may have resulted from the calcareous nature of the matrix.

It will be seen that the observations I have made respecting the distribution of the Tertiaries on the eastern plains are very disjointed and unsatisfactory. As the Cretaceous strata overhanging the Winnipeg group of lakes appear to dip to the west, again to rise to the *Côteau des Prairies*, it is probable that the trough which they thus formed was occupied by Tertiaries of the same age as those that cover the Cretaceous strata on the Upper Missouri; but that, in the immense denudation that has taken place, they have been unable to withstand the erosion so well as the tough clays that underlie them, which had therefore remained as a shoal further out to sea, while along the shore the more yielding strata were being rapidly ground down under the combined action of currents and stranded ice.

Although it is probable that Tertiary basins occur in the plains further west, especially some of the groups that yield lignite, these will be afterwards described along with the Cretaceous strata, as there is an absence of data by which to discriminate them.

CRETACEOUS SYSTEM.

Nearly the whole of the great area of prairie country from the eastern axis to the Rocky Mountains is occupied by Cretaceous strata, which have attained an enormous development throughout the central portion of the North American continent.

The classification of these strata, as they occur in the prairies to the south, has been worked out during the last six years by Messrs. Meek and Hayden with great success, and the results have been published as memoirs in the 'Proceedings of the Academy of Natural Sciences, Philadelphia.' The Reports of the various Pacific Railway exploring expeditions also give details and descriptions of the fossil remains which have been found in this group.

Messrs. Meek and Hayden divide the Cretaceous System of the Upper Missouri into five groups; but my observations were not sufficiently extended to warrant my referring the different Saskatchewan strata to these without much doubt, more especially as I had not the benefit of their valuable reports, which were published while I was engaged in the exploration. In the following vertical section I have therefore adopted a different method of lettering, only indicating the probable equivalents of their section. In the case, how-

ever, of one group (E), Mr. Meek has identified the strata from fossils submitted to him by Mr. Hind. The groups in my section do not perhaps truly represent successive periods in time, but rather indicate the different conditions that existed in the geographical areas in which they were deposited.

Vertical section, in descending order, of the Cretaceous System, as developed in British North America.

F. Arenaceous clays and sandstones, with *Scaphites, Nautilus, Avicula*, and other marine *Mollusca*. No. 5 of Meek and Hayden.	Observed by Hind on South Saskatchewan below the Elbow. Lower part of section at La Roche Percée? At the elbow of Battle River?
E. Indurated olive-coloured shales, with bands and fissures filled with clay-ironstone. *Leda Hindi, Ostrea Inguhris*, scales of Ctenoid Fishes, Annelide-tubes, and Plant-remains. Also observed by Hind, *Natica, Ammonites*, &c. No. 4 of Meek and Hayden.	Forms the high grounds cut through by Long Creek and the Souri River. Also at the Forked Creeks near the Assineboine.
D. Dark-purple and brown laminated clays, with ironstone-septaria, and sometimes crystals of selenite. *Baculites, Inoceramus, Pholadomya, Cardium, Exogyra, Astarte, Cytherea, Ammonites*. No. 3 of Meek and Hayden.	Valley of Assineboine at Fort Ellice. Elbow of South Saskatchewan, Eagle Hills, and on North Saskatchewan to Fort Pitt. On north slope of Cyprés Mountain. In the Gulf of Georgia, on Vancouver's Island, at Nanaimo River, Saltspring Island, and at Valdez Inlet, by McKay.
C. Sandstone overlying marly clays, banded with thin seams of ironstone, thin beds of limestone, stiff dark-blue clay, and arenaceous shales. *Ostrea cortex, O. vellicata, O. anomiaformis, Cytherea, Mytilus, Cardium, Venus, Natica*, &c. Stems and roots of silicified trees.	Battle River? Hand Hill's, Red Deer River. (Not observed on west side of Rocky Mountains.)
B. Great lignite-group*; sandstones coarse and friable, or argillaceous and concretionary, indurated shales, and soft limestones, ironstone-nodules, beds of lignite 3 to 10 feet thick: silicified wood, *Taxites*, and sedge-like stems in the sandstones. No. 1 of Meek and Hayden. Includes the Wealden (?).	Red Deer River, North and South Saskatchewan, Athabasca, and Pembina Rivers, &c. Nanaimo, Vancouver Island, Bellingham Bay, Burrard's Inlet, Gulf of Georgia, &c. The position of this group is not clearly made out to the east of the Rocky Mountains, as the sections at the first and second localities are, so far as is known, contradictory. The beds at Battle River, Edmonton, and Lower Red Deer River may be Upper Cretaceous or even Eocene.
A. Green sandstone and conglomerate at base of lignite-group at Nanaimo, tufaceous sandstone-conglomerate, much altered, and containing *Trigonia Emori, Cytherea Leonensis, Arca* (2 sp.), *Psammobia, Exogyra* (2 sp.), *Ostrea* (2 sp.), *Rostellaria, Pecten*, &c. Jurassic?	Fossil Point, Departure Bay, North of Nanaimo in Vancouver Island.

* It is possible that the lignite-bearing group B, which occurs in two lines

Bituminous shales, resting on limestone and covered by friable sandstone. The shale takes fire and burns spontaneously.
The limestone contains fossils that are Jurassic (?).
[From these shales perhaps come the two species of *Ammonites* described by Hind.]

Described as occurring on the Mackenzie River by Richardson.
Similar bituminous shales on the North Saskatchewan and on the Athabasca where it cuts through to outer range of the Rocky Mountains. Containing *Ostrea* and *Cardium*.

[For comparison with the foregoing section I give three sections of the Cretaceous beds and the Tertiaries immediately overlying them, extracted from the Reports of the Mexican Boundary-commission, vol. i. p. 126 *et passim*, where an able digest of their relations is given—prior, however, to the most recent of the researches of Meek and Hayden.

First. *Section of Eastern States. New Jersey.*

Nos. 4 and 5 of Meek and Hayden.

VIII. Upper greensand beds (3rd).
VII. Coarse and fine beachsand.
VI. Middle greensand beds (2nd).
V. Quartzose sand, indurated and concretionary, with oxide of iron.
Exogyra costata, Ostrea larva, Belemnitella, Pecten.
IV. Lower greensand beds (1st), marly clays.
Exogyra costata, Ostrea larva.
Gryphea, Ostrea vesicularis.
III. Dark-coloured clays, greensand in patches.
Ammonites Delawarensis, A. placenta.
A. Conradi, Baculites ovatus, and casts of *Cardium*.

In this position should be Nos. 2 and 3 of Meek & Hayden.

No. 1. of M. & H. { II. Dark clays with *fossil wood*.
I. Fire- and potter's clay, *fossil leaves and wood*.

Second. *Section of Strata on Mexican Frontier.*

Tertiaries of west coast. *Miocene.*
Tertiaries east of the mountains; sandstone, sands, and conglomerates like those of the Mauvaises Terres in Nebraska.
Calcareous beds with marine Eocene fossils underlying unconformably the preceding strata.

Cretaceous.

1. Argillaceous beds. *Exogyra costata.*
2. Calcareous beds, buff- and lead-coloured, with beds of white limestone.
Gryphea Pitcheri, Cardium multistriatum, Toxaster, Holectypus, Ammonites Texanus, Hippurites, Nerinea, Caprina, &c.
3. Sandstones of various colours with beds of clay.

Carboniferous.

Third. *Section from the Missouri westward.*

Tertiary indurated clays, sandstones, conglomerate, and limestone, with mammalian and chelonian remains, and fresh-water shells.

Cretaceous.
Nos. III. IV. & V. of the New Jersey Section.
5. Arenaceous clays, argillo-calcareous sandstones. 80 feet.
4. Plastic clays, concretionary calcareous sandstone. 250 to 300 feet.
C. & D. of Nicollet. } This is the principal fossil-bearing bed of the Upper Missouri.

separated by a belt of clays like C, may include deposits of two different ages—the one Upper Cretaceous or Eocene, like the beds at La Roche Percée, and the other Cretaceous, in the position assigned to it in the section.

A. & B. of Nicollet.	3. Calcareous marl, *Ostrea congesta*, *Inoceramus problematicus*, scales of Fishes	100 to 150 feet.
	2. Clay with few fossils	80 feet.
Nos. I. & II. of New Jersey.	1. Sandstone and clay with fossil wood	90 feet.

"The change from III. to IV. is always well marked.

"*Inoceramus problematicus*, which is the same as *I. fragilis*, is the characteristic fossil of Nos. II. and III., and with *Ostrea congesta* ranges to Mexico.

"These latter groups everywhere rest on the sandstone and clay beds (No. I.), which are the 'Jurassic' of M. Marcou.

"With the exception of two species, the Cretaceous fossils of the Mexican frontier are distinct from those of the New Jersey section, and nearly equally so from those of Nebrasca; whereas the latter or Nebrasca section, extending from the Missouri westwards, has many fossils in common with those of New Jersey and Alabama. It is therefore probable that the Mexican beds represent a different epoch in the Cretaceous series from those of the east and north-west. However, from the Mexican frontier no sections were obtained to show whether one or more groups were represented."—Rep. Mex. Boundary-commission, vol. i. p. 126.]

Group F.—In speaking of the Tertiaries, I have mentioned the only places where it is probable that the route of the Expedition touched on the strata of this group—viz. at the height of land of the Qu'appelle River and at La Roche Percée, where the lower sandstones may perhaps be of this age.

Group E.—By reference to the map, it will be seen that the first point where the route of the Expedition passed over Cretaceous strata, was after gaining the great plain of which Pembina Mount forms the eastern limit, at Long River, latitude 49° 8′ N., longitude 98° 35′ W., which is a tributary of Pembina River, flowing northwards. This stream flows through a deep valley in the high plateau stretching back from Pembina Mount, and in its gulleys are exposed sections of group B. It is a compact shale of light greenish-drab colour, not occurring in continuous layers, but as fragments with irregular conchoidal surfaces, which have been produced by the desiccation of what were originally thin layers of clay. Sometimes it has more of a slaty character. Among these beds are hard bands and nodular masses of dark-brown clay-ironstone, and perpendicular fissures are common, which are filled up with splintery iron-shale. Also small coloured tubes traverse the strata perpendicularly in large numbers.

The same strata were observed at Forked Creek, where a deep gulley joins the valley of the Assineboine in latitude 50° 6′ N., and longitude 101° 18′ W., and these two places are both on a line of high hilly ground, which stretches in a north-west direction, no doubt marking the outcrop of the shales. At Long River they dip gently to the south, and are covered by 6 feet of pure white sand, very incoherent; and over this lies the Drift, consisting of light-grey calcareous earth. At Forked Creek they seemed to be strictly horizontal, and were covered by a local drift derived from the subjacent beds. Mr. Hind, who also saw the beds at Forked Creek and other localities, submitted the fossils which he obtained to Messrs. Meek and Hayden; and they have referred them to their second highest group. He gives the following list as named by them*:—

* Rep. Sask. Exploring Expedition, p. 180.

Anomia Flemingii.	Natica obliquata.
Inoceramus Cedarensis.	Avellana concinna.
Leda Hindi.	Ammonites (sp. indet.).

Of those from my collection has been determined the *Leda Hindi*; and, in addition, *Ostrea lugubris*, scales of Ctenoid Fishes, Annelide-tubes and Plant-remains were also found. Traces of these beds were observed to the south of the Qu'appelle River, and also on the North Saskatchewan on the left bank, a considerable distance above the Eagle Hills. Mr. Hind also observed them to form part of the high escarpment of the Duck and Riding Mountains which overhang the lakes, reaching an altitude of 1000 feet; and it was at 500 feet from the summit that he detected these strata.

The group has not been distinguished from the next on the map which accompanies this paper; but, from the more resisting texture of these shales, it is probable that they occupy a larger area of the lower plains that have been subjected to such great denudation than any other group of strata.

Group D.—At Fort Ellice the banks of the Assineboine are 240 feet high, and in general their structure is obscured by vegetation, but at one point a recent slide displayed a partial section of the bank. The upper part consisted of the comminuted fragments of the last-described shale, along with beds of pure sand, and also the more common yellow drift. Close to the water's edge, masses of strata of tenacious calcareous clay were exposed, of a dark-purple colour, but presenting a weathered surface decomposing into a ferruginous earth. Along with these strata were two beds of soft clay-ironstone about 4 feet apart; the lower one half a foot thick and rather compact, the upper one concretionary, forming thick nodulated masses, the surfaces of which show the *cone-in-cone* structure. At this place only a few fragments of the nacreous shell of *Baculites* were found, but sufficient, along with the mineral resemblance, to identify these beds with group D in the vertical section. At the elbow of the South Saskatchewan, where that river cuts through the great prairie-côteau, the boulder-drift is seen to rest on strata of purple clay (fig. 1, p. 395), with nodular masses of ironstone, having veins and cavities filled with calc-spar. These Septaria are in great numbers, and, when broken, are found to include fragments of the following fossils:—

Baculites compressus.	Cardium.
Inoceramus (*I. Crepsii* of Roemer and Conrad).	Exogyra.
	Astarte Texana.
Pholadomya occidentalis (*Morton*).	Cytherea.

The outcrop of these Septaria-clays has a clear relation to the great prairie-ridge which is cut through by the South Saskatchewan at this point, and continued to the north-west by the Eagle and other hills to near Fort Pitt, where it hems in the North Saskatchewan in like manner, the banks having an altitude of 500 feet, and also displaying sections of the strata with the same fossils. At the base of the Eagle Hills, and wherever they prevail, they form lofty and ruinous banks, the strata breaking away in great slices, which slide forward successively. I have counted as many as thirteen such slides

on the bank of the river; the oldest, though now close to the water-level, still bearing part of the original prairie-surface, with the same turf that once grew 200 or 300 feet above its present position. The result of this is, that it is seldom that anything can be learnt of the strata which form the full thickness of the river-banks, the more superficial beds being repeated again and again in each slip, so as to give a very exaggerated idea of their development. Above the elbow of the South Saskatchewan the strata are very dark, and contain a large quantity of selenite in radiating crystals. Portions of those soft strata have been formed at this place, by the action of the weather and of the river on their base, into lofty conical mounds, which present a most extraordinary appearance. As no grass has time to grow on them from the constant attrition of their surface, they are perfectly black, and their outline is broken into terraces by the successive lines of ironstone-concretions, which from their hardness retain the soft strata underneath them. At the base of the Cyprés Mountains, where these hills begin to rise from the plains that lie between them and the South Saskatchewan, the sides of the *coulées* are formed of the same Septaria-clays, with fragments of *Inocerami*, and presenting the usual rugged features. This locality would be very favourable for the study of the whole Cretaceous group and the overlying Tertiaries which form the summit of the high lands of the Missouri Côteau, were it not so dangerous on account of the different hostile Indians that move about in strong parties through it. The Expedition only spent a very few days at this interesting place, as it was here that we broke up into parties to explore the Rocky Mountains in 1859. From the few observations I was able to make however, I have been induced to carry the line of these strata from the elbow of the south branch along the *côteau* to the Cyprés Mountains, besides their outcrop to the north-west, along the line of the Eagle Hills to Fort Pitt. In the prairies this and the other groups of the Cretaceous System preserve an unaltered condition, and rarely present other than a most gentle dip; but close to the Rocky Mountains, and also within the plications of the older rocks forming that chain, altered shales, highly charged with iron and resting on sandstones, were observed, which at the time I was inclined to consider to be these Septaria-clays, as the concretions had a very great resemblance to those of this group.

Similar beds with *Inocerami* were also observed at Nanaimo on Vancouver Island, but I shall describe the whole strata at that place together, and for the present confine myself to the development of the Cretaceous System in the Eastern Prairies.

Group C.—A very large proportion of the higher plains to the west of the Eagle Hill Côteau is occupied by the fourth great group of the Cretaceous strata. It is met with forming the banks of the lower part of Red Deer River, near where the Expedition crossed it during the last summer's explorations. From that part it rises to the westward, until, at the Hand Hills, the sandstone which forms its upper member has preserved it as outliers, having abrupt escarpments to the west. By its marked lithological character it was also

recognized on Bow River to the south for a considerable distance above the mouth of Belly River, and also yet further to the south-west, forming the high broken grounds over which I passed on my journey from the Cyprés Mountains to the Rocky Mountains in August 1859. It was also met with at the elbow of Battle River, and above Fort Pitt, on the North Saskatchewan, where it seems to form the banks of that river for a considerable distance, but is wanting above the Snake Portage, until it reappears again at the Pyramids about 100 miles above Fort Edmonton. Between these points it probably forms the high grounds back from the river, such as the Beaver Hills, Bears' Hill, and the hills round St. Ann's to the west and north of Edmonton. I offer this sketch, however, of its distribution more as a surmise founded on the physical features of the country, than from actual observations of its relations at these various points.

Excepting very obscurely below the Snake Portage on the North Saskatchewan, I cannot say that I anywhere observed the relation of this group to the Baculite-clays of the preceding division. I descended that river on the ice, travelling with dogs, in March 1858, and as the late season compelled me to travel a great deal in the night I missed many points of interest. Its relations to the strata below it were apparently shown on Red Deer River.

At this place the group is found to form the broken country round the base of the escarpment of the Hand Hills, which probably in their full altitude include several of the members of the Cretaceous System, and therefore merit a more minute description.

These hills form a high mass of table-land a few miles back from Red Deer River, presenting an abrupt escarpment to every quarter but the east, in which direction they slope off gently with the dip of the strata.

Our encampment on June 25th, 1859, was in one of the deep ravines on its western face, 375 feet above the plains below, and 160 feet below the level of the plateau above.

In the upper part of the escarpment facing the S.W., grey coarse sandstones were exposed, which had a considerable dip to the N.E. The bedding of these was hard and distinct, and they were seen to rest upon soft incoherent sandstone underlain by light sandy clays and blue-clay shale (see section, fig. 5). In the clays are enclosed angular masses of black iron-shot sandstone, and also pebbles of quartz and granite. No evidence of the exact position of these strata was obtained; but, although they were somewhat disturbed, I saw no reason to doubt that they are a superior member of the Cretaceous series overlying the beds next to be mentioned, which are of the group C. Fig. 5 (p. 418) gives a sketch of the strata of the hills from the valley of Red Deer River northwards; and it will be seen that there is an interval of several hundred feet between the sandstones and clays and the banded clays of group C, the nature of which was not ascertained. These banded clays, which occupy a narrow belt of country round the Hand Hills, give rise to large white mud-swamps, which we found at the season of our visit to be nearly dry.

and presenting a very rough surface from the floundering of the large herds of buffalos in the tough plastic clay bottom as they had been eagerly striving for the last trace of water. These clay beds, which contain a large proportion of calcareous matter and are often "banded" by thin seams of soft ironstone, have a white chalky aspect, and are so easily acted on by the weather that what were originally gulleys soon expand into wide flats bounded by conical hills, with bright surfaces marked regularly at every few inches by the parallel streaks of ironstone, which are often only half an inch thick. From these swampy flats, that serve as reservoirs for the water which descends from the hills in spring, the streams have worn deep ravines which join the valley of Red Deer River. At the commencement of one of these, or near the base of the group C, the "banded clays" were seen to rest on red iron-clay shales in thin beds, underneath which is a bed of rotten limestone of a buff colour, which again rests on a bed of shell-conglomerate, principally composed of fragments of *Ostrea cortex* aggregated into a solid rock with many complete specimens of the same shell. Mr. Etheridge has identified this shell, which is a species described by Conrad in the Mexican Boundary Commission Reports (p. 157). Together with *Ostrea multilirata* it was found at Dry Creek, Mexico; and, in describing them, Conrad says that he knows no species like them in the Cretaceous System, and that probably they belong to strata of still earlier date. However, at another locality, near the Hand Hills, I again found *Ostrea cortex*, and along with it *O. vellicata* and *Cytherea Texana*; and these are undoubted Cretaceous shells of Mexico. From between El Paso and Chihuahua, which seem to be places within a few miles of each other, the following list of fossils is quoted in the Mexican Boundary Report—*O. velli-*

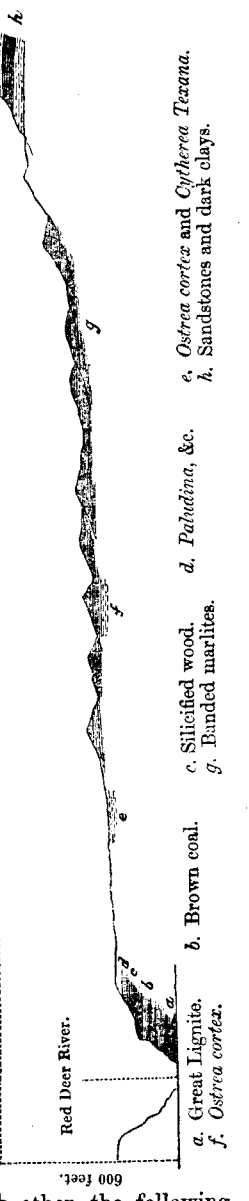


Fig. 5.—*Section from the Red Deer River to the Hand Hills: the Middle Cretaceous and Lignite Groups.*

cata, *Cytherea Texana*, *Exogyra* (2 sp.), *Trigonia Emori*, *Arca*, and *Nodosaria*,—thus including both fossils found in the neighbourhood of the lignite on Red Deer River, and also some that were found along with that of Vancouver Island.

On Battle River, in latitude 52° 17′, the banded clays were also observed with the same features and with the same fossils. From that river to Red Deer River they appear to form the surface of the country, as every shallow ravine shows slides of the white chalky beds, and the white mud-swamps are very common. At the "elbow" of Battle River, the strata have a slight easterly dip; and in the upper part of the bank were obtained in a concretionary sandstone *Avicula*, *Cardium*, *Cytherea*, and *Baculites compressus*.

A little higher up the river, and towards the base of the bank, *Ostrea cortex* was found, as on Red Deer River. For fifteen miles above this point the valley is cut through these strata; and then the banded clays are seen to form the higher portion of the banks, still with rolled fragments of *Ostrea* at their base in some places, and resting on strata containing silicified wood, which form the lower part of the bank, while in the bottom of the valley the true lignite appears.

Group B.—In my next and lowest group I have (with great hesitation) classed the large deposits of coal or lignite, of the Prairie-country, that are sufficiently compact to be of value as fuel, but which have hitherto been generally classed as of Tertiary age.

However in all the sections which have been given of the Cretaceous System in the United States, it will be observed that the lowest beds are always described as sandstones containing fragments of fossil wood. Further, Dr. Hayden has pointed out that, at the base of his Lowest Cretaceous group fresh-water beds occur, in which the shells are more nearly allied to Tertiary forms, and that the vertebrate remains, of which only a few bones have been obtained, are considered by Dr. Leidy to belong to an equivalent of the Wealden period in Europe. In the same horizon has also been found angiospermous leaves, such as *Quercus*, *Salix*, &c. At the same time he remarks that the fossils from the Judith River beds of the supposed Wealden age cannot be distinguished in many instances from those of the great lignite-basin, which he knows to be Tertiary beyond doubt, mentioning as instances an *Ostrea* and a *Trionyx* that were considered common to the two formations. It may therefore be justly concluded that this question is one of great nicety and doubt, which will only be slowly cleared up as those vast territories become explored. Nevertheless, we are by these observations prepared to consider as possible at least the existence of a coal-bearing formation at the base of the Cretaceous System, even though developed to an extent not hitherto recognized*. In his description of the lignite-formation on the Mackenzie River,

* Since writing the above, I have seen a paper by Dr. Hayden, published in 1857, and before the only other memoir of his that I had access to, in which he suggests that his Lowest Cretaceous group may be only an extension of the lignite-group which extends from the Arctic Ocean, but which, like that group at Judith, may be mixed up with Tertiary strata, also containing lignite.—Proc. Acad. Nat. Sci. May, 1857, p. 116.

Sir John Richardson refers to strata of a similar nature as occurring at Edmonton on the North Saskatchewan; and, on first arriving at that place in January 1858, I had no difficulty in identifying the beds there with those which he describes. I got not only the same yew-like leaf (*Taxites*) that he figures as characterizing the shales, but also the same general succession of strata, excepting only the beds of shingle and gravel, which he describes in his sections of the Mackenzie River. Before leaving England, Colonel Lefroy furnished me with the following extracts from his notes on Peace River, a point midway between the Mackenzie and Fort Edmonton, which are sufficient to show that the strata are probably continuous throughout this area. He observes that "at the ramparts on Peace River is a vertical cliff of sandstone with broken stratification towards the top," and that "at Dunvegan the river is depressed 600 feet below the general level, and great quantities of crystals of sulphate of lime were collected in the upper strata, while actual coal occurs in the seams about ten miles above the fort on one of the small tributaries." The lignite-formation has also been remarked on Smoking River, a tributary of Peace River; and I have traced it on the Athabasca and McLeod Rivers, and on Pembina River, all to the north of Edmonton; thus proving the range of this formation over a slope rising from 500 to 2300 feet above the sea, and yet preserving on the whole the same characters, and showing no evidence of recent local disturbance beyond the gentle uplift which has effected this inclination.

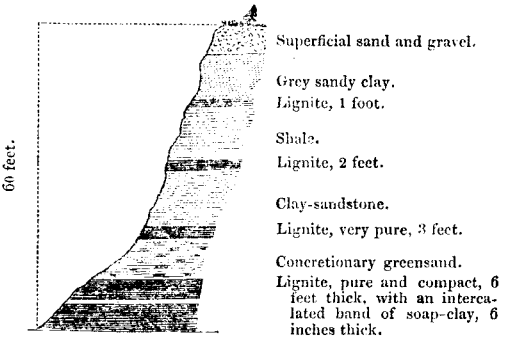
I shall now describe this formation as it was observed in different parts of the country explored, commencing with the North Saskatchewan. The lowest point on that river where the coal was actually observed, was about two miles below Fort Edmonton, where a thick bed of it was seen dipping gently out of sight below the water-level to the N.E. I have reason to believe, however, that other beds of it occur further down the river for a distance of 50 or 60 miles.

At Fort Edmonton the flanks of the river-valley are from 190 to 250 feet high, and at most places densely wooded. Seven to ten miles back from this valley, on either side, a line of high ground rises from 200 to 300 feet above a willow-covered plain, and consists, as far as I could learn, of the white marly clays of the group D; but the country in this neighbourhood is much obscured by superficial deposits and by small copse-wood. The river-valley has a wide flat bottom through which the river winds in a channel 40 to 60 feet deep, and wherever this present channel sweeps close under the higher valley-banks, sections are displayed, disclosing horizontal strata of arenaceous clays, sometimes passing into clay-sandstone with spherical concretions, but at others into clay-shales. Many of these beds are highly charged with nodules of clay-ironstone, which are filled with comminuted fragments of vegetable matter. The coal occurs in the clay strata, and varies greatly in purity. It is used in the forge at the fort, and is found to answer very well, excepting that it "burns" the iron more than ordinary coal. It ignites with difficulty, but keeps alight for a very long time, and, if left to itself without a draught, smoulders away into an abundant orange-coloured ash. It contains a quan-

tity of water in its composition, as, although generally compact, like fine bituminous coal, when first excavated, it soon splits up into fragments which have dull earthy surfaces. There is a great difference in the quality of this lignite or coal, according to the bed from which it has been procured, and also the distance from the outcrop to which the seam has been worked. There are no sinkings of any sort into any of the seams, the manner of procuring the small supply which is required for use at the fort being for the blacksmith to go down to the river-bank with a pick, and procure a few basketfuls where he can most easily get access to the material.

The fort stands about 100 feet above the water-level, and below it in the bank there are two seams of 18 inches each, but on the opposite side of the river, at a little distance below, there are several seams exposed, the principal of which, close to the water's edge, is 6 feet in thickness; and there is one a little way higher where it is 4 feet, with others less pure (see fig. 6).

Fig. 6.—*Section of the Right Bank of the Saskatchewan River near Fort Edmonton.*



In the middle of the 6-foot seam there occurs a layer, 5 to 8 inches thick, of magnesian steatitic clay, which works up into a lather like soap, and is used by the women at the fort for washing blankets.

A sample from the 6-foot seam has been analysed, at the same time with the Lignite from La Roche Percée (see p. 409): Mr. Tookey's results are as follows:—

Carbon	50·60
Hydrogen	3·24
Nitrogen	0·90
Oxygen	14·41
Sulphur	0·42
Ash	15·93
Water (hygroscopic)	14·50
	100.00

"The colour of the ash in each case was buff. When heated in a close

vessel, neither of the lignites yielded a coherent coke, the residue retaining as nearly as possible the shape and bulk of the original particles. The gas which was expelled during the process possessed but feeble illuminating powers. Both samples contain a large percentage of water that can be expelled with a temperature of 100° C. This appears to be a characteristic feature in the composition of lignites."

The gravel- and shingle-deposits are seen to rest on the cut edges of the coal-bearing beds, and are therefore of more recent date. They contain fragments of the nodules derived from the underlying strata, along with pebbles of quartz and other rocks, that must have been derived from elsewhere. Also large fragments of silicified wood are found in the subsoil at Edmonton, the same as that found in the upper part of the lignite-group on Red Deer River, as will be described.

At the bend of the river below the fort, and on the same side, the bank looks as if broken tiles had been strewn over it. This arises from the coal having at one time been completely burnt out, only being represented now by a thin layer of ash, while from the baked clays above and below the red tile-like material has been derived. Amongst these fragments I obtained impressions of the same Yew-like leaf that Sir John Richardson found in the beds at the Mackenzie River under similar circumstances, but along with dicotyledonous leaves, of which I however found no trace.

For ninety miles up to the North Saskatchewan, above Fort Edmonton, the grey arenaceous clays prevail, forming the banks of the river, which are high and precipitous, the valley for that distance making a succession of abrupt bends after every few miles of a straight course, its main direction being to the north.

The secondary banks are also gradually lost, until at length, from the valley narrowing, the river occupies its full width. Above this point, however, the valley suddenly widens and preserves on the whole a straight course from the west, independent of the windings of the river itself, which has a very tortuous course between secondary banks, crossing from side to side of the great valley round heavily timbered flats. Where the river sweeps under the high banks, sections about 200 feet high are exposed of white variegated marls, which are cut in the most regular manner by gulleys into pyramids, with a most artificial appearance as seen from the river, their bright chalky surfaces being thrown into strong relief by the dark-green pines that clothe the ravines. These marls have much the look of those of group C.

Fifteen miles below the mouth of Brazeaus River, which is a large tributary to the North Saskatchewan from the west, we again meet with the lignite-bearing arenaceous strata, and from this point they were traced uninterruptedly to the base of the mountains. The formation now presents very different characters from those at Edmonton, having more the appearance of a shore-deposit. The mineral composition is very varied, and large deposits of sandstone occur, which is fine- or coarse-grained, but never makes any approach to a conglome-

rate. At the Rocky Mountain House, in latitude 52° 21′ N., longitude 115° 10′ W., where I had the best opportunity of examining this formation, I divided it into three groups, judging from the mineral composition alone; as they were found to pass from one to the other without superposition, just as we might expect to find in a shallow lagoon-deposit.

1st. Coarse-grained sandstone, composed of angular grains of quartz cemented by calcareous matter, present in small quantity. This sandstone forms bold perpendicular cliffs, often 150 feet in height, and hemming in the river on both sides. It resembles the descriptions given of the sandstone of the "ramparts" on the Mackenzie and Peace Rivers; and indeed on all the rivers this formation may be traced by this marked feature as far south as the Missouri at least, as a drawing of the falls on that river (given in Pac. Rail. Rep.) exactly resembles these sandstone cliffs.

The 2nd group consists of beds of green argillaceous sandstone, which, as it weathers easily, always gives rise to sloping banks, from which protrude concretionary masses. These beds are generally horizontal, but sometimes present a rapid dip towards the edges of basins in the last group in which they seem to have been deposited. They are, however, often overlain by the hard-bedded sandstone.

The 3rd group more resembles in its mineral characters than the other two the beds at Edmonton, consisting of alternations of clay-shale and argillaceous sandstone in irregular beds, and including deposits of coal or lignite. The shales, which are often very hard and compact, contain fragments of the Yew-like frond, and also stems of plants like sedges.

Fig. 7 (p. 424) is an attempt to combine the different sections that were observed at the Mountain Fort. The irregularity in the mineral composition is well shown about five miles above that place, where in a very short distance beds of clay and soft green sandstone are suddenly replaced by cliffs of grey and yellow sandstone with heavy bedding*.

* The features of the strata at the Mountain House are very similar to the description given of the Lower Cretaceous groups at Seargent's Bluff on the Missouri by Meek and Hayden, where the following section is described:—

"1. Dark-coloured clay with sandstone seams	6	feet.
2. Light-yellow clay passing into grey sandstone	5	,,
3. Dark clay with fragments of carbonized wood	1½	,,
4. Grey indurated clay or marl with wood	4	,,
5. Dark seam like No. 3.	8	inches.
6. Clay like No. 4.	3	feet.
7. Grey sandstone (carbonized wood)	2	,,
8. Very dark-grey clay, sometimes black, with organic matter in the lower part, and crystals of selenite	10	,,
9. Grey clay, carbonized wood and hard concretions	30	,,
10. Grey sandstone with wood	2	,,
11. Grey clay, with wedge-shaped masses of hard bituminous lignite or coal and round lumps of sulphuret of iron, to the river-level"		

It is mentioned that the beds thin out in many directions, and that some increase to a great thickness in a few hundred yards.

(Mexican Boundary Rep. vol. i. p. 136.)

As developed at the Mountain House, this formation, whatever its exact age, may be described as consisting of sand and clay in varying proportions—great ridges of pure sandstone, including basins in which have been deposited clays and clay-sandstones charged with coal and ironstone in large quantities.

On the Athabasca River, the valley from Fort Assineboine in latitude 54° 50′ up to the outer range of the mountains at Deadman's Rapid, cuts through argillaceous sandstones, with beds of clay and coal of the same kind as those at the Mountain House. The sandstones are in much greater proportion however, and the lignite-beds are more rarely seen, than in the sections along the North Saskatchewan. At Deadman's Rapid these strata are succeeded by grits and clay-shales in regular beds, undisturbed at first, but, on approaching the mountains, found to be implicated in the late upheavals.

On Red Deer River the lignite-formation was observed at various points, the lowest being at the Hand Hills, which have already been alluded to in speaking of the "banded clays." By again referring to fig. 5 (p. 418), it will be seen that a flat plain extends back from the summit of the river-valley towards the base of the hills where the white mud-swamps are situated, but which is cut up by great ravines, which gradually deepen as they approach the river. The river-valley itself is half a mile wide, and 270 feet deep.

At the commencement of one of the ravines, about three miles back from the river, were found the fossils before mentioned (*Ostrea cortex*); and in another, at only a quarter of a mile back from the river-valley, that fossil was again found in the highest part of the bank, along with *Cytherea Texana*, showing that these beds must form the surface of the level flat. At the mouth of the same ravine (Shell Creek), the following sections were observed in the bank of the valley of Red Deer River, the beds being to all appearance horizontal:—

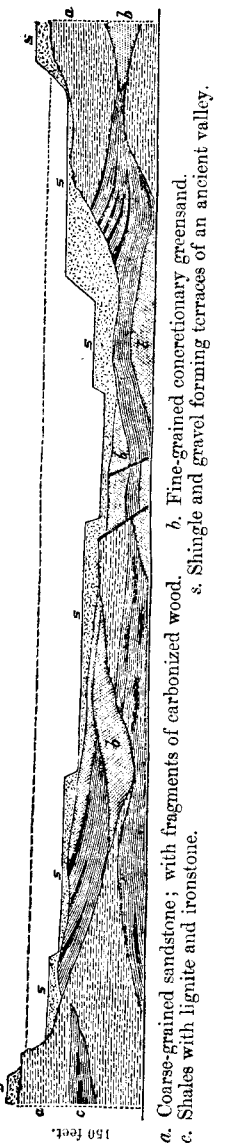


Fig. 7.—*Sections along the Saskatchewan River, at Rocky Mountain House, combined in order to show the variation in the beds and the terraced arrangement of the Superficial Deposits.*

a. Buff, unstratified, earthy clay.—12 feet.

b. Ash-grey and cream-coloured sandy clays in bands with thin seams of clay-ironstone and carbonaceous layers ("Banded clays").

Throughout this bed are angular pebbles of ironstone which look like fragments of septaria.—30 feet.

c. Seam of pure lignite ("cuboidal lignite")—3 feet.

d. "Banded clays" very sandy in some places. In other places the coal has been burnt out and the heat has converted the upper beds of this group into material like broken tiles, which lie scattered over the banks. Probably the ochre-beds observed in some parts of the banks are the layers of ash which represent the lignite-bed when consumed.

f. Brown coal. This bed is about 18 inches thick, and in thin leaves, with a paper-like texture; on it rests—

e. 1 foot of silicified wood, composed of stems and trunks, and roots of large trees. In the bed these are of a deep brown-black colour, but the fragments which lie scattered about weather to a light-cream colour on the surface. One silicified root measured 18 inches in diameter.

g. Sandy clays partially banded, varying from grey to light-cream colour. Crystals of selenite are very common, but no large masses were observed. This group has a very chalky look from a distance. It is probably 100 feet thick, but the base of the section was not observed.

Although these beds are very variable, passing horizontally into different varieties of shales, banded clays, and sandstones, still there seemed to be a definite inclination to the N.E., so that in ascending the river deeper beds were exposed.

A few miles above Shell Creek the lower part of the banks are to a great extent composed of a bed highly charged with ironstone nodules, which have very irregular shapes, unlike the nodules in the other parts of the strata. The profusion of these strewn on the slopes of the valley reminded me of the heaps of roasted ironstone scattered in the neighbourhood of iron-furnaces. A little way further on, where a creek joins the valley, thick beds of coal appear at the base of the section. The lowest bed is 4 to 5 feet thick, and very compact and pure. It is included in the same gritty sandy clay that everywhere forms the matrix of the coal.

The iron-shales immediately overlie these beds, and these are again overlain by the "banded clays" that form the base of the section lower down. By following up Coal Creek for a few hundred yards to where the banks attained a height of 250 feet above the burnt lignite-seam, I found in a hard sandy limestone-bed the following fossils:—

Ostrea anomiæformis.	Crassatella.
Mytilus (2 species).	Venus.
Cardium multistriatum.	Rostellaria.

Paludina.

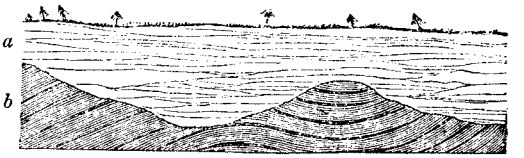
No break was observed in the beds, and the succession of the strata

from the lignite upwards was such as might be expected in a gradual passage from freshwater to marine deposits. I did not, however, remark the layer of silicified wood or brown coal that I expected to occur above the "banded clays" that overlie the lignite.

On Battle River similar beds were observed in lat. 52° 28′ N. long. 111° 29′ W., having the same order. The high part of the section was composed of the "banded clays" along with concretionary masses of sandy limestone, containing *Ostrea*, *Avicula*, and other shells. Over the "banded clays" is the layer of silicified wood, while at the base of the section and under the water of the river the beds of lignite crop out.

For sixty miles above the Hand Hills I had no opportunity of examining the banks of Red Deer River, but at the mouth of Bull Creek the strata were found to present much the same appearance as at that place; the higher banks consisting of the "banded clays," while along the river are exposed the beds of lignite overlain by the silicified wood. Beneath the lignite, and what must be the lowest bed of the section at this place, occurs a hard grey sandstone with large concretions, that contain a slight admixture of lime, and in these I obtained several leaves of deciduous dicotyledonous trees. The exact spot where these were obtained is just below the mouth of Deadman's Creek. A little above this place the coal forms beds of great thickness, one group of seams measuring 20 feet in thickness, of which 12 feet consist of pure compact coal, and the remainder of carbonaceous clays. At one point the seam was on fire, the bed exposed in a cliff of about 300 yards in length being at many places in a dull glow, the constant sliding of the bank continuing to supply a fresh surface to the atmosphere. For miles around the air is loaded by a heavy sulphurous and limey smell, and the Indians say that for as long as they can remember the fire at this place has never been extinguished summer or winter. For ten miles above this place the coal-beds were traced as we ascended Red Deer River. They are then succeeded by cliffs of sandstone apparently formed by beds overlying the coal-group, but the dip is very slight. The Nick Hills where this sandstone forms a high ridge run to the north-west, and above this point the banks of the river are composed of finely laminated marly clays, often containing concretionary masses of limestone filled with freshwater shells, such as *Paludina*, *Planorbis*, &c.

Fig. 8.—*Section on the Saskatchewan River, 20 miles above Rocky Mountain House.*



a. Buff calciferous sandstone resting on the lignite-group (*b*) unconformably.

These marly clays overlie the sandstone of the Nick Hills, and

seem to occupy a great basin, through which the river flows from above the forks of Medicine River. Traces of a similar deposit of much more recent date than the lignite-group on which it rests, were noticed on the Athabasca River and also on the North Saskatchewan, as shown in fig. 8.

Above that point there appear chocolate-coloured shales with beds of sandstone; and on Little Red Deer River a section (fig. 9) was ob-

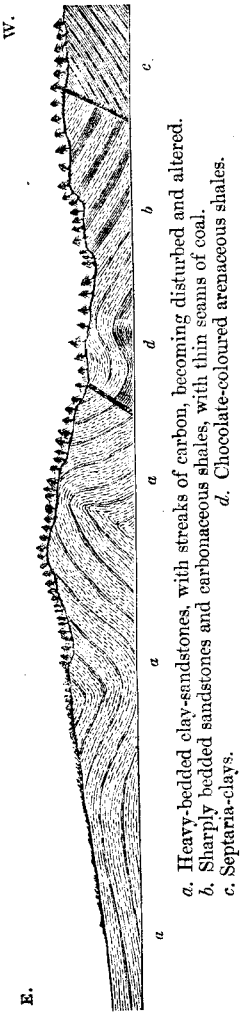


Fig. 9.—*Section of the Exterior Range of the Rocky Mountains, on Little Red Deer River.* Length 7 miles; height 600 feet.

a. Heavy-bedded clay-sandstones, with streaks of carbon, becoming disturbed and altered.
b. Sharply bedded sandstones and carbonaceous shales, with thin seams of coal.
c. Septaria-clays.
d. Chocolate-coloured arenaceous shales.

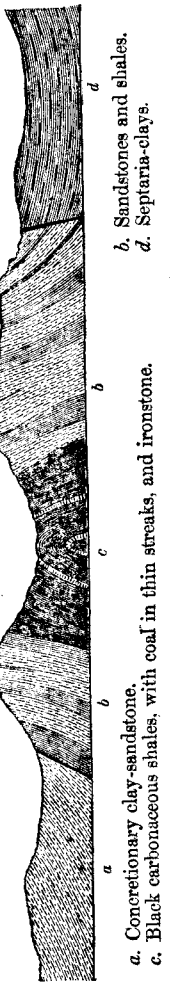


Fig. 10.—*Section along Dead-man River, near the Old Bow Fort.*

a. Concretionary clay-sandstone.
b. Sandstones and shales.
c. Black carbonaceous shales, with coal in thin streaks, and ironstone.
d. Septaria-clays.

served, in which the sandstone beds become disturbed and harder, presenting beautiful flexures and exposing at the base the same shales.

Relations of the Cretaceous Series on the West.—On Weepaioos Creek, a tributary to Deadman's River, and within fifteen miles of the Old Bow Fort, thin disturbed beds are very distinctly exposed, as in fig. 10, and must include an enormous thickness of strata. Although in the absence of fossils I cannot speak positively, yet I believe that these sections include Carboniferous strata, which are represented by the lower grits and shales, which contain coal in thin streaks with plant-impressions. From some of the higher beds at the Bow Fort, a small *Cardium* was procured. Also on the North Saskatchewan, over the grits and shales of probably Carboniferous age, there came beds of pink quartzose grit with dark shales, on which rested a great thickness of black aluminous shale containing a small *Ostrea* in great abundance. Also on the west shore of Lac à Bruler, where the Athabasca River leaves the mountains, the same strata were observed resting high up on the flanks of a mountain of Carboniferous Limestone.

At many other points in the mountains throughout the eastern ranges, patches of shales occur, highly ferruginous and along with grits and heavy-bedded sandstones of various tints, and having apparently a superior position to the rocks of Carboniferous age, of which the greater mass of that portion of the mountains is composed. In the sections of the various mountain-ranges, the beds which I consider to belong to this group I have lettered *a*, and, as they are of great thickness, it is probable that they represent some of the strata that are found undisturbed in the prairies. In the exterior range of mountains on the North Saskatchewan, masses of thick-bedded encrinital limestone rise to the height of 1500 feet with a heavy dip to the west; while the pink grits and aluminous shales dip away from them in every direction, just as if they had been masses of intrusive rock thrust up from below,—thus showing the want of conformity between these limestones and the strata that I consider to intervene between them and the Cretaceous.

Cretaceous Strata of Vancouver Island and the Gulf of Georgia.—The map No. V*. is from the Admiralty-chart of the straits between the south end of Vancouver Island and the mainland, but extended northwards so as to include the portion of the coal-mines. On it I have sketched-in the probable range of the different formations, but in a very imperfect manner, as my own observations were only the result of a trip made in a canoe with four Indians for seventy miles up the coast to Nanaimo. At Nanaimo coal has been worked by the Hudson Bay Company since 1854, and the total export up to January 2nd, 1860, has been about 12,000 tons. Through the kindness of Mr. Nichol, the gentleman in charge of the works, and of Mr. Pearce, of the Land-office, I am able to show a map of the neighbourhood, in which I have inserted my own observations of the Geology (Plate XIII.). At the time of my visit there were three

* It was not thought necessary to publish this map.

pits in operation, giving employment to thirty miners and a number of labourers. The former are principally Scotch and Staffordshire men that have been brought out to the country at the Hudson Bay Company's expense, but the greater number of the labourers are Indians, small tribes of whom come and settle at the mines and work for a short time until they tire of the uncongenial life, when they leave to make room for another band. The irregular supply of labour from this cause adds greatly to the uncertainty and expense of the workings. When working in the best seams at Nanaimo, a miner can put out 2½ tons per day. The shipment from Nanaimo in the month of January 1860 was 2000 tons, the trade having at that time been suddenly extended by the demand consequent upon the establishment of gas-works at Portland, Oregon, and several other places. This demand was supplied from a large stock that was lying on hand at the time, but which, from having been exposed to the action of the weather for many years, was of very inferior quality. In spite of this, however, I understand that the market has continued steady throughout last year, and that the coal has been much used in California for making gas instead of that brought from the Eastern States as heretofore. Coal from the same description of strata has been also worked to some extent on the opposite side of the Gulf of Georgia at Bellingham Bay, and also at Coose Bay in Washington Territory. Although it has been found in many other localities along the coast, as I shall mention after describing the formation, these are the only places where it has been worked to any extent. The whole formation associated with the lignite- or coal-beds is very extensively developed along the Pacific coast, and has generally been considered to be of Tertiary age, excepting from the first accounts sent home, which, as there were no fossils, induced geologists to consider them as Carboniferous. Some fossils transmitted to the Jermyn Street Museum many years ago were first rightly recognized by the late Professor E. Forbes as being Cretaceous; but the localities were undescribed, and, in the absence of sections, it was impossible to deduce anything from them regarding the age of the coal-beds.

The observations which I have now to offer respecting these strata will, I believe, put their age beyond doubt as Cretaceous; but rightly to understand the value to be attached to them requires me to give first a sketch of the physical features of the district.

The southern part of Vancouver Island, where the town of Victoria is built, is composed of metamorphic rocks, with occasional beds of crystalline limestone. This district and also the central portion of the island, as may be expected from the formation, is everywhere hilly and even mountainous, with only limited patches of fertile soil in the valleys. However, the scanty soil on the rocky hills supports a fine growth of timber, so that they are almost invariably wooded to their summits. In the immediate neighbourhood of Victoria there is nevertheless a good deal of fine open land dotted with small oak-trees. On passing to the north through the Canal de Haro, the islands of the archipelago between Vancouver Island and the mainland are seen to be composed of strata of sandstone and conglomerate, which form

lofty cliffs overhanging intricate but beautiful inlets. The junction between these two formations was not observed, but I think it is south of San Juan Island, thence crossing to Vancouver Island by Sannich Point, and northwards a little way back from the coast, leaving a narrow strip of fine land*.

These sandstone and conglomerate strata have a uniform strike from N.N.W. to S.S.E., and, in passing along the shore of Saturna Island, they were observed to form several well-marked synclinal troughs, and on passing through the Plumper Pass to dip gently to the N.E. under the waters of the Gulf of Georgia. The nature of the beds was not ascertained beyond the general fact that they are thick-bedded sandstones and conglomerates, and sometimes strata of clay-shale. The sandstones are much acted on by the weather, and at the water-line the sea has generally worn in them caves and hollows. The conglomerates form the highest beds of the series, and are of immense thickness.

After passing the Plumper Pass, in proceeding north through Trincomalee Channel, Galiano Island to the west presents cliffs, about 800 feet high, of the sandstone and conglomerate, with a gentle dip to the east; and sometimes spits or low promontories of the strata run parallel with the coast, enclosing narrow bays. The west side of the channel on Salt Spring Island is a low shelving coast heavily timbered to the water's edge, and exposing outcrops of grey and blue clay-shales, which dip to the east. The portion of this island which is occupied by these shales is the finest land for settlement I have seen on the coast; but the southern part is mountainous, rising to the height of 2300 feet. It is on the north part of Salt Spring Island that the saline springs are situated from which it gets its name. They seem to escape from the shales, and occur in spots clear from timber and covered with green moist vegetation abounding in saliferous plants. Round the orifices from which the brine escapes, there have formed conical mounds of granular calcareous sinter stained with

* I am informed by Lieut. Roche, R.N., that, when stationed on that coast, he discovered a copper-lode, and detected it on Moresby Island and various points in a line running S.E. by E., as indicated on the map. I have not myself seen the samples he brought away, but copper in the metallic state is known to exist in quantities further north, and I have a specimen of the sulphide of copper which was said to have been found by the Indians on the mainland. There is no doubt that a careful examination of Vancouver Island and the adjoining mainland for metallic veins would yield valuable results. Since my return to England I have heard that the same silver-ore that is found at Washoe, and that raised such a furor in San Francisco a year ago, has also been found on the mountains of Fraser River. The Cascade range of mountains may be looked on as the continuation of the Sierra Nevada of California, and the marked change in the nature of the coast-line north of Vancouver Island shows where the chain begins to dip down to the sea-level; so that what were formerly mountain-valleys are converted into inlets and straits. This is a most important physical feature, and the great facilities for access to the mineral wealth of the country which it affords will exert a powerful influence on the destinies of British Columbia, although at present, in the absence of roads, its iron-bound coast and want of rich flat country are erroneously considered as a bar to its development. Sooner or later it will be seen how wonderfully this new colony is adapted by nature for mining, fisheries, and commerce.

iron; but in summer there is said to be an abundant deposit of pure white salt.

North of Salt Spring Island the strata preserve the same strike and general appearance all the way to Nanaimo, the island forming long spits of sandstone and conglomerate with precipitous shores to the west. Just below the "rapids" the shales were again noticed, resting on the sandstone, and both dipping to the west. At very low tide a thick seam of lignite is exposed at this point and on the island opposite, and to the east I found a thin seam in the sandstones. At Nanaimo the sandstone country occupies a broader belt along the shore of Vancouver Island than further to the south, but immediately to the north the strike changes to nearly east and west on Newcastle Island; and on Fossil Point the lowest beds were seen to rest on igneous rocks, which continued to occupy the coast for the few miles I went further to the north. At the head of the Gulf of Georgia, the sandstones again form the islands that crowd the narrow channel that separates Vancouver Island from the mainland, and also a great extent of both shores. From Comux and Valdez Inlet, which are situated in this locality, some of the fossils which I have were procured by Mr. McKay, of the Hudson Bay Company. Also at the extreme north end of the island, at Fort Rupert, Mr. Lord, of the Boundary-commission, observed the sandstones and thick beds of lignite dipping out to sea.

At many points along the eastern shore of the Gulf of Georgia, these strata have been detected with the associated lignite-beds. North of Howe's Sound the mountains closely hug the sea-coast, but south of that they retire along the north shore of Burrard's Inlet to the south-east, so as to be sixty miles inland where the boundary-line meets them; thus leaving a very heavily timbered track, which forms the only level country in British Columbia west of the Cascade Range. Most of this district is covered by shingle-terraces and other superficial deposits which obscure the underlying strata, but from Burrard's Inlet, eight miles north of the entrance to Fraser River, coal and sandstones containing fossil leaves have been sent home by H. M. S. "Plumper." Also on Fraser River near Fort Langley, and on its tributary Pitt River, the coal has been observed, and then again at Bellingham Bay, south of the boundary-line; so that it is probable that these strata underlie the greater part of this region.

Details of the Strata at Nanaimo.—In the section, fig. 3, Plate XIII., I have represented the whole beds observed at Nanaimo in their probable order, but I did not see any one section giving the complete sequence expressed in it. Starting from Fossil Point, north of Departure Bay, we have the high promontory formed of trap, resting on which are beds of greenstone-conglomerate, consisting of spherical masses of greenstone, cemented by a felspathic matrix. Over this is a tufaceous bed (with imperfectly formed crystals), 5 to 6 feet in thickness, partly fused and often pierced by the trap from below. Then follows a very tough green sandstone quite filled with shells, for many of the specimens of which I am indebted to Mr. McKay.

The following is the list as determined by Mr. Etheridge:—

Trigonia Emori.	Exogyra (2 species).
Trigonia (sp.).	Ostrea (2 species, one of which is of great size).
Cytherea Leonensis. (This is the most common shell.)	Rostellaria.
Arca (3 species).	Psammobia (?) sp.
Pecten*.	

In speaking of the beds on Red Deer River, I referred to the fossils found at this place as showing the existence of forms which are in Mexico associated with those of the Saskatchewan, and in every case found in the proximity of the lignite-beds. Thus in particular we have *Cytherea Texana*, common to the Saskatchewan and Mexico, and *Trigonia Emori*, common to Mexico and the Pacific coast. This, owing to the very imperfect state of our knowledge and the limited extent of the collections, is probably to be considered as merely an indication of the agreement that may yet be established. The green sandstone beds at the base of the series which contain the lignite seem to have been deposited originally on the surface of the igneous rock, which was probably submarine, so that its surface, chilled by the water, easily broke up into the masses that compose the conglomerate-like breccia, the cement of which has been derived from the tufas that were deposited on its surface. On the shoal thus formed the greensand beds had been deposited, enclosing the molluscous remains. The whole has since been repeatedly disturbed, and some of the lower beds have undergone partial fusion by more recent outbursts.

The sandstone is sometimes quite horizontal, but at others quite vertical for a little way, and is only found as patches all round the promontory and north side of Departure Bay.

Three hundred yards from the shore in the channel that passes between Newcastle Island and the Fossil Point, is a row of islands composed of very fine conglomerate that might be termed "gravelstone," in beds that dip S.S.E. at 15°. These beds contain small fragments of carbonized wood.

A quarter of a mile further on, in the direction of the dip on the north end of Newcastle Island, there are high cliffs of sandstone, which preserve the same direction. They seem to be rather more disturbed than the strata that form the islands in the channel, but this appearance is exaggerated by the great amount of false bedding. The strata of sandstone continue to preserve the same direction of dip all along the coast of Newcastle Island, but gradually becoming more horizontal towards the southern extremity. On the west side of the Island at Exit Channel occur the seams of coal, the lowest of which has been worked to a considerable extent, while the existence of the other has only been found by boring. The outcrop of these two seams has been ascertained on the east shore of the island, where

* It is probably from this place that the fossils were procured to which Meek and Hayden refer in a notice of the coal of the Pacific coast, contained in the Pacific Rail. Rep. vol. vi., where they say that among the fossils from Vancouver Island a number occur in a green sandstone matrix, which have a strong Jurassic aspect

they have the same characters and relative position, thus showing that they are continuous to that extent. The lowest bed of coal is called the "Newcastle seam," and is worked by levels driven into the outcrop as it rises with the high bank from the shore. The coal or lignite is 6 feet thick, with a floor of sandstone, and a roof of a very tough conglomerate of very small pebbles. The strata have a dip of 20°, so that the method employed succeeds well for taking out small quantities.

This mine was not being worked when I visited it, but there were large heaps of the coal, waiting for a market, that had been lying there for some years, so that I could judge the effect of the weather on it with great facility. The surface was turned to a rusty brown, and the masses showed a tendency to break up with a slaty fracture—otherwise the exposure had worked but little change.

Along the shore of the island to the south, the strata of argillaceous sandstone are seen to dip steadily in the same direction with less and less inclination, until at the southern extremity they are almost horizontal. On Douglas Island there is said to be another seam of coal, from the shales associated with which the fossil leaves are generally procured. I had not an opportunity of visiting it, however. On the coast at Nanaimo Harbour the strike of the strata is quite different, but yet they preserve the same character and sequence, Exit Channel seeming to mark a great fault. The little peninsula on which the Hudson Bay Company's establishment stands, and where the coal was first discovered, is also another dislocated portion of the strata, as may be seen by reference to the map.

At Nanaimo, as on Newcastle Island, there are two seams, the "Newcastle" and the "Douglas,"—the first of which is everywhere about 6 feet in thickness, with sometimes a floor of fire-clay, but more generally of sandstone, and the roof consisting of the fine conglomerate bed, about 60 feet thick, on which rests the Douglas seam with an average thickness of from $3\frac{1}{2}$ to 4 feet. The roof of this seam is sometimes of iron-clay-shale, but more often of the same tough conglomerate that it rests upon. On Chase River, $1\frac{1}{4}$ mile to the south, the outcrop of a seam has been discovered and worked to a small extent, which they consider to be the "Newcastle seam;" and as it occurs right in the line of strike, and as they have ascertained the outcrop at several points, it is probable that the beds of coal are continuous.

In the mines they have met several "stone-faults" or "swells," where the floor rises up and throws the coal-seam out for several fathoms. It is generally represented, however, by a carbonaceous parting. These faults are a source of great expense in the working, as the conglomerate to be pierced is exceedingly tough and compact, so that the blast only brings it away in small pieces.

In proceeding along the coast towards the mouth of Nanaimo River, the strata consist of argillaceous sandstones with a similar character to those of the southern part of Newcastle Island, and preserving a steady though gentle dip to the E. by S. A short way above the en-

trance to the river, in the sandstones, there is a thin seam of coal, the position of which was pointed out to me by Mr. Nichol, as the river was too high to allow us to see it. Continuing to ascend the river, which is of small size, we found low exposures of the sandstone still with the dip to the E.; and at Fossil Bank, three or four miles from the mouth, they are overlain conformably by dark-purple clays filled with septaria, which yield Cretaceous fossils. The dip of the beds is 10° to the E. by N., and the clay strata were clearly seen to rest on the hard-bedded sandstones.

I found *Inoceramus*, *Baculites*, and some other fossils, of which other specimens are also among those obtained by Mr. Bauerman at this place. I was told at Nanaimo that *Ammonites* have frequently been found there of large size, and from Mr. McKay I got a number of fossils, some of which he obtained at this locality; but others having the same appearance, and also contained in septaria, he procured from Comux and Valdez Inlet at the head of the Gulf of Georgia; but these two sets of specimens had been unfortunately mixed together. For a couple of miles the Nanaimo River flows through these clay strata, and then turns again from the S.W., and in ascending the sandstone strata were again found to recur as in the lower part of the river, but with a more rapid dip. At the "Cañon" these sandstones form precipices about 100 feet in height, bounding a narrow gorge 600 yards long, through which the river flows. The beds dip at 15° to the E.N.E., and are very like those of Newcastle Island.

From under these sandstones, in ascending the river, hard beds of the gravel-conglomerate cropped out with great regularity, separated by soft beds of red and greenish clay. These probably correspond to the group with the coal at Nanaimo, but I failed in finding any proof of it beyond fragments of carbonized wood. The strata from Fossil Bank up to the river, as far as I went, are shown in section No. 3, Pl. XIII.

The total thickness of the beds from the coal to the clays at Fossil Bank I estimated at 600 to 700 feet, but I had no opportunity of making any exact measurement. Between Nanaimo River and the coast, there is a tract of very fine country, and it is probably occupied by the Septaria-clays, which, as I mentioned before, were seen a little south of the rapid.

The following is the list of fossils from the Septaria-clays, which includes those specimens obtained by McKay from Valdez Inlet:—*Inoceramus* (?) (this is the *I. Crepsii* of Conrad and Roemer), *I. Texanus*, *I. Nebracensis*, *I. unduloplicatus*, *I. confertim-annulatus*, *I. mytiloides*, *Baculites compressus* and two other species, *Ammonites geniculatus* and three other species.

It is thus evident that the group of strata with the lignite-seams towards their base must be of Cretaceous age; but as yet it would be premature to infer the exact position which they hold with reference to the rest of that system. The great beds of conglomerate which form the long narrow islands along the west of the Gulf of Georgia must, I think, overlie all these strata.

From the sandy shales associated with the lignite, I forward fragments of Yew-like fronds, just the same as those I got in the shales. At the Rocky Mountain House, and in the collection sent home by H.M.S. "Plumper," all the specimens from Nanaimo are of this plant. Those from Burrard's Inlet are in a different stone, are reticulate leaves, and were also found along with beds of coal; but there seem to be no specimens of the Yew frond from that locality*.

From Nanaimo Mr. Bauerman has also sent home a plant that looks much like a portion of a monocotyledonous leaf.

At Bellingham Bay, sections taken by Mr. Pemberton show that the lignite occurs in a large quantity at that place. Lieut. Trowbridge in describing the strata there says, they are 2000 feet thick, and include, in all, 110 feet of the lignite-coal. His sections are probably, however, all of the same group of strata, taken at different points in the strike, which gives rise to this apparently enormous thickness.

The analysis of the coal from Bellingham Bay, which is generally considered inferior to that of Nanaimo, is given in the Pac. Rail. Report, vol. vi. p. 65, as follows:—

Carbon	47·63
Bitumen	50·22
Ash	2·15
	100·00

This coal has been sold in San Francisco market at from $18 to $22 per ton (75*s.* to 91*s.* 6*d.* sterling).

Lignite-coal has also been worked for the same market from Coose Bay, and has the following composition:—

Carbon	46·54
Gaseous matter	50·27
Ash	3·19
	100·00

Conrad states that shells from this locality are of Miocene age.

At Benicia, above San Francisco, coal also occurs, and was wrought for some time, but the dip was too steep.

In Newbury's Report on the geology of this part of California, I have not seen any notice of where this Benicia lignite occurs in his sections; but between Benicia and the sea he describes 3000 feet of strata, the lowest beds being of sandstone and shales resting on, and penetrated by, serpentine and trap (the same which are so highly charged with ores of copper and mercury further to the south). These are followed by green and brown shales, coarse soft sandstone, fine sandstone and shales, with *Pecten*, *Natica*, *Mactra*, and *Tellina*, and these by conglomerates and tufas, the whole lying at an angle of 30°. Towards Benicia are thin-bedded clays with Sharks' teeth. Up Feather River, a tributary of the Sacramento River, at Chico Creek,

* Dr. Hooker has specimens from Disco Island, in the arctic regions, where a Yew frond and angiospermous leaves are associated in the same hand-specimen.

a calciferous sandstone is described, containing *Nucula*, *Mactra*, and other Tertiary forms; but from the same place are *Baculites*, *Inoceramus*, and *Ammonites*, which Meek considers as proving the existence of Upper Cretaceous strata at that place. So that it is probable that there are strata of both ages, but included in the same disturbances; and it is not unlikely that the section from Benicia to the sea may also include Cretaceous strata*.

The existence of coal or lignite on the Pacific coast, of quality fit for the purposes of raising steam, is of great commercial importance, and that obtained from Nanaimo is as yet admitted to be the best in the market. If these beds are therefore discovered to be persistent, so that they can be worked to advantage on a large scale, there is little doubt that this coal, even though it be an imperfect substitute for the finer coal to which we are accustomed in this country, will form a valuable source of wealth to the new British colony. Already it is extensively used by the British navy on that station, and it was found to require only a slight modification in the method of feeding the fires to make it highly effective as a steam-generator.

As beds of coal of similar quality exist in the Islands of Japan and Formosa, we should thus have the supply of fuel at the extremities of the line of the great sea-voyage, if the route from England by the Canadas, Saskatchewan, and British Columbia to China and the East were adopted—a natural fitness not to be overlooked in considering such a scheme.

PALÆOZOIC ROCKS OF THE EASTERN AXIS.

The general structural features of the country travelled over on the canoe-route, so far as they can be learned from a single line of traverse, have already been well described by Mr. Keating, Sir John Richardson, Dr. Bigsby, and others; but, from the complicated relations of the rocks of which it is composed, no detailed observations can be of any value until they are extended in every direction by means of a combined topographical and geological survey.

The whole of this district is occupied by a primitive axis—the "intermediate primitive belt" of Sir J. Richardson—which is composed of gneiss, mica-schist, crystalline limestones, and other metamorphic rocks, with intrusions of granite, probably of very different ages, the whole formation being the Laurentian series of Logan, corresponding, it is thought, to the fundamental gneiss recently described by Sir R. Murchison as underlying the most ancient strata in Scotland.

From observations made in the course of our journey, it appears that there are two distinct directions of strata in the rock which compose this axis, marking it into two districts, one from Lake Superior to Rainy Lake, the other from Lake of the Woods to Lake Winnipeg. Not only the general strike of the altered and upheaved rocks

* On the Colorado River the Texas lignite or coal, in beds 4 feet thick, has been observed in strata under those with Eocene fossils, and on a tributary of the Del Norte, beds, 3 to 4 feet thick, occur of good working quality, in true Cretaceous strata. (Pac. Rail. Rep. vol. vi.)

in these two districts, but also the direction in which the water-courses affect the principal descents, and the manner in which the lakes in each of them are arranged, all indicate a different direction of the elevating and disturbing force; in other words, two different axes of dislocation.

These seem to converge towards the south, including an angle of about 25°; the eastern one being directed from the north-east to south-west, while the western one lies much more nearly north and south. In each of these there is a great central district where nothing but rounded bosses of granite are seen occurring as ridges and islands, which rise little above the level of the flooded country in which they occur. On either side of these two granitic districts metamorphic rocks are ranged with great irregularity as regards their order and dip, but still, on the whole, preserving their direction very consistently with the bearing of the axes to which they respectively belong. There are besides many minor outbursts of granite occurring as dykes and intrusions, but they do not seem to interfere with the above-mentioned general bearings of the country.

From this cause, in crossing the district between Lake Superior and Rainy Lake, the summit-level is reached by an abrupt and rapid ascent in a direction at nearly right angles to the main eastern axis. Then follows a long traverse, almost along the summit of that axis, and then an abrupt but comparatively short descent to Rainy Lake, again at right angles to the axis.

The first great step in the ascent from the east is made at the Kakabica Falls, where, from a succession of faults which mark the commencement of the more highly metamorphosed rocks, a sudden elevation is effected, the summit-level of which is 179 feet above Lake Superior at Fort William.

About one mile below the fall a fine section is exposed in the form of a cliff 130 feet high, crossing the country from north-east to south-west, consisting of a dark argillaceous schist in thin fissile beds, from 1 to 2 inches in thickness, very much jointed, and having many small veins of quartz, and sometimes calc-spar, included both in the lines of bedding and in the joints. These beds are quite horizontal, and through their whole thickness the river has cut its way back to the present position of the fall in a manner similar to that in which the river-bed below the Niagara Falls has been formed.

They are supposed to belong to the Huronian series, a system which is largely developed on the shores of Lakes Superior and Huron, resting unconformably upon the Laurentian series, and having, according to Sir W. Logan, a thickness of 12,000 feet. This large system, that has not as yet yielded any fossils, and always underlies the Silurian, has been considered to represent the Cambrian.

On the River Kaministoquoiah above the fall at Friar's Portage the strata have an almost vertical position; and a little further on, at Lower Island Portage, are found to be dipping at an angle of 40° to south-south-east, and to be changed in character, having mica developed in them, and also a great abundance of quartz-veins. Imme-

diately afterwards, in the course of the ascent, true granite occurs, and after several alterations schistose flags reappear at Upper Island Portage, but now dipping at a high angle to the north-west.

From the falls to the Dog Lake the ascent of the river pursues a northerly course, crossing the beds obliquely by a succession of minor falls, giving rise to scenery of unequalled beauty. At the Dog Portage another sudden rise takes place in the water-level; for the rocky high grounds which, for a long way below, have been skirting the river at some distance, forming, as it were, the limits of a wide valley, here converge and form a granitic barrier across the river, the summit of which is about 719 feet above Lake Superior, and 440 feet above the river at the lower end of the portage, but only 140 feet above the lake-level at the upper end, thus making a rise in the water-level of 297 feet in the short distance of two and a half miles. As the portage-road passes right over the top of this hill and leads to a point in the lake far from the exit of the river, the nature of the rock at the falls which produce this sudden change in level could not be examined, but the mass of the hills seems to be granite. Although this is not the highest point of land over which we passed during the route, still it is probable that this hill is as high as any portion of the rocky axis of the country; as those along the lake are inferior to it in elevation, while the ascent which is made after leaving the upper end of Dog Lake is through a swampy country covered with drift. In fact, after leaving Dog Lake, until a considerable descent has been made to the west, no rock is exposed, the whole summit-level being covered with a thick deposit of drift.

From the Lake of the Thousand Isles, where the rocky flooring of the country is again uncovered, until Sturgeon Lake is reached, the descent is very slight, and the route follows a chain of small lakes, which are in most cases detached from one another, being separated by rocky barriers over which the canoes and cargoes are carried.

In many cases the lakes are at exactly the same level at each end of the portage, and the greatest difference between the two ends of any of these portages is only about 35 feet, so that the total descent in this part of the route cannot amount to very much. This chain of lakes may, in fact, be considered as occupying a line parallel with the summit of the watershed, and the country in which they lie is almost wholly composed of granite, occurring in broad round eminences, nowhere rising to 100 feet above the level of this half-drowned country. It is probable that this granitic belt is expanded considerably where the old portage-route crosses it, and that the whole chain of lakes between Lake Rasiganagah and Sturgeon Lake lies within it. It is this belt which will form the great obstacle to the formation of any kind of road across this watershed.

From Sturgeon Lake to Bad River there is a considerable descent to the south, which forms the only exception to the general north-westerly descent of the waters to Rainy Lake.

From the Lake of the Cross to Lake Namucan the descent is rapid,

and the river-channel crosses the strata of gneiss and bedded greenstones at right angles, following the direction of the dip.

Rainy Lake has its length agreeing with the strike of the strata, which is here more nearly east and west than before.

Between Rainy Lake and the Lake of the Woods the superficial deposits again cover all rocks from view, and when the north end of the latter lake is reached and they are again exposed, their general strike is now changed to almost north and south, agreeing with the greater axis of the lake, just as Rainy Lake agrees with the strike of the eastern district. The descent from the Lake of the Woods to Lake Winnipeg is by successive groups of falls, between which the river forms lake-like expansions, which lie generally at right angles to its main course.

The first part of the River Winnipeg flows across vertical strata, and then enters a granitic district very similar to that passed through between the Lake of the Thousand Isles and Sturgeon Lake.

The strike of the rocks in this region is generally a little to the east of north, and the nature of the strata is very similar to that of the country east of Rainy Lake, but less disturbed by dykes.

No trace was observed of the existence of the schistose rocks on the west flank of the axis, the gneissose rocks continuing for the whole way to Lake Winnipeg.

Silurian Rocks.—Mr. Hind, who had favourable opportunities, from having coasted along Lake Winnipeg and the other lakes that lie in this formation, gives an interesting account of its development in his recent work ('Canadian, Assineboine, and Saskatchewan Expl. Exped.' ch. xxxviii.): his fossils having been submitted to Mr. Billings of the Canadian Geological Survey, the following groups were identified as occurring in the Winnipeg basin; all of them are Lower Silurian:—

1. Chazy Formation.
2. Bird's-eye Limestone.
3. Trenton Limestone.
4. Hudson River Group.

Of these I only saw the last at the same place that Dr. Owen examined and recognized the proper age of the beds in 1848—namely, at the Lower Fort Garry on Red River. Here there is a bench of magnesian limestone exposed in the bed of the river when the water is low, and which is then quarried for building-purposes. As the river was high when I was there, this section was not visible, but from fragments lying on the bank the following fossils were obtained:—

Cyathophyllum.
Columnaria alveolata (*Hall*).
Favestella (Favosites basaltica of *D. Owen*).
Receptaculites occidentalis (*Salter*).
Ormoceras Lyonii (*Stokes*).
Strophomena plano-convexa.
Orthis; var. of *O. Lynx*.
Spirifera elegantula.
Maclurea.
Rhynchonella incubescens (*Hall*).

These fossils have been named for me by Mr. Salter, who has kindly examined the few palæozoic fossils that were procured. The limestone is subcrystalline, of a light-buff colour with purple blotches,

very hard, and having an angular fracture. At Stony Hill, about fifteen miles north-west from the upper fort, there is an isolated bluff of limestone rising from the plain-level to the height of 80 feet. The south and western exposures are abrupt and waterworn, it having evidently been at one time an island; and indeed during the great floods which have several times inundated the settlement it has been one of the few spots upon which the inhabitants can take refuge, reaching it by means of boats. The beds of limestone are horizontal or nearly so, and are slightly different from those at Fort Garry in their mineral aspect, having a more crystalline structure and the colour being of a reddish hue. No fossils can be discovered in newly fractured portions, but on the weathered surfaces a few obscure remains of fossils are to be seen projecting, together with siliceous and gritty particles, from a dull floury surface.

The Silurian rocks have now been traced continuously from Lake Superior west of the sources of the Mississippi, and thence into the valley of Lake Winnipeg and on to the Arctic Ocean, skirting the more ancient axis. On the shore of Lake Winnipeg they have been observed much disturbed and even vertical by Dr. Owen ('Report on Geol. of Minesota,' &c.), but in general they rest nearly horizontally, or with only a very slight dip.

Resting on the Silurian strata, Mr. Hind has detected limestone with Devonian fossils in a tract to the west of Lake Winnipeg, where there are copious salt-springs, the brine from which is used for the manufacture of salt. He considers the line marked by the occurrence of these salt-springs to indicate the outcrop of the Devonian strata.

The route of the Expedition at once passed from Silurian to Cretaceous rocks without any indications of the intervening formations until reaching the Rocky Mountains.

STRUCTURE OF THE ROCKY MOUNTAINS.

Physical Character.—The plains at the eastern base of the Rocky Mountains are, as I have before stated, elevated above the sea 4000 feet; and, as the average limit of vigorous vegetation in that latitude is attained at 5000 to 6000 feet, the greater mass of the mountains displays in consequence naked and bald surfaces, which are generally very precipitous. Their structure is thus easily discerned to be of strata the real thickness of which, originally very great, has been much exaggerated by the complex flexures which cause the beds to recur again and again, sometimes even in the same mount. The apparent confusion is so great from this cause as to strike the eye at once, and it is not until observations have been made over a considerable extent of the range that the extreme regularity with which the disturbing agencies have been exercised becomes evident. The flexures of the strata on the eastern part of the mountains have been so completely inverted that the prevailing dip is towards the centre of the mountains—that is, to the W. and S. The strike of the plications varies, but in a regular manner. From Bow Fort, southwards, it is only a few degrees east of south; but north of that river

to the valley of the North Saskatchewan its average direction is S.S.E., and between that valley and the Athabasca it is S.E. nearly, while to the north of that it is changed to within two points of east and west. These changes in the direction of the strata take place at the different great valleys by which these rivers leave the mountains, and which probably mark the lines of transverse fracture. The mountains are divided into groups by great longitudinal valleys, which are met with in every part of the chain that I examined, running in the length of the range and forming a part of each of the river-systems. The course of these rivers is, therefore, in every case zigzag, alternately flowing through wide valleys either to the north or south, and then making short breaks to the east or west through narrow and rugged defiles.

Throughout these great valleys it seems to be the arrangement of the detrital deposits that has in many cases determined the direction in which the rivers flow.

A curious feature is to be remarked in the position of the water-shed between the waters of the Pacific and those of the Atlantic, arising, no doubt, from this cause. It is found gradually to occupy a position further to the west, and through the chain, so to speak, as the rivers rise more to the north.

Thus the Missouri can hardly be said to rise within the Rocky Mountains at all. Belly River, on the boundary-line, rises from the first ridge before reaching the first longitudinal valley. Kananiskis River rises in that valley, or from the second range; Bow River from the third range; the North Saskatchewan from the fourth range; the Athabasca from the fifth; and, although I have not seen Peace River, the one further to the north, still this feature is so well marked that it has been spoken of as rising on the west side of the Rocky Mountains and then cutting through that range to the east. This all tends to show that we must not look on the Rocky Mountains as a continuous range, stretching as a line of fracture through the length of the continent, but rather as a succession of centres of disturbance, a fact which has been amply proved within the American territory.

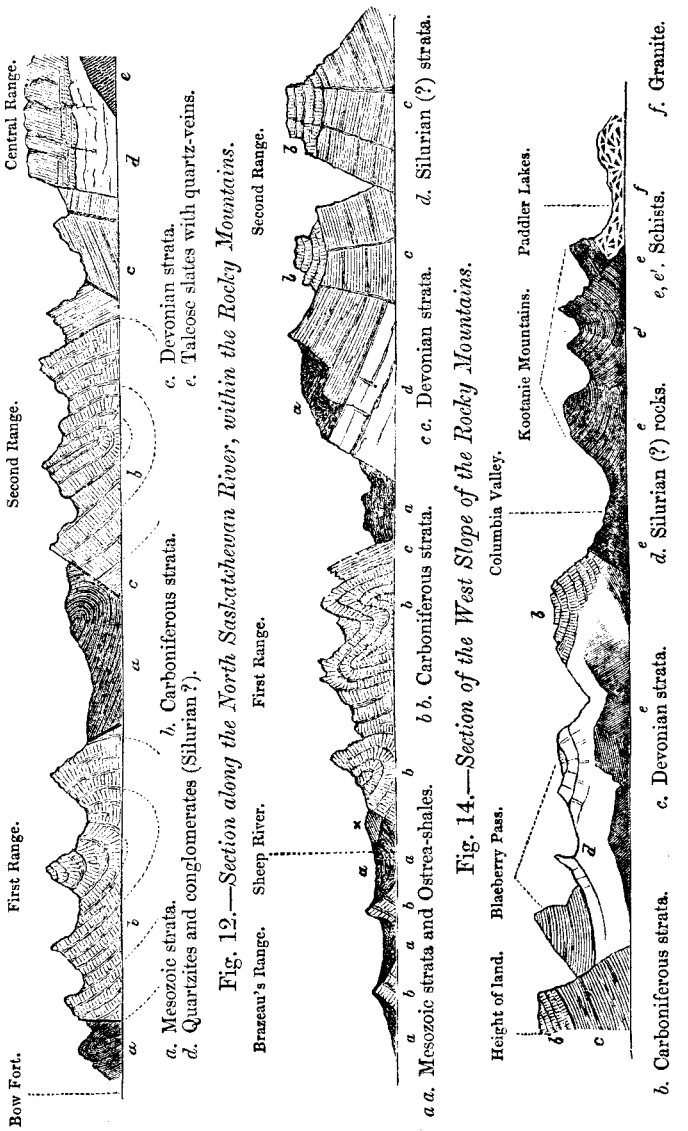
Thus what are known as the Rocky Mountains at the head of the Missouri are rounded off to the north and south, losing their character of a lengthened range in that of a mass of mountain-country.

In like manner the Rocky Mountains within the British territory must be looked upon as a mass with its longer axis lying N.N.W. and S.S.E., with which the main strike of the strata conforms.

Geological Structure.—There are three of these great longitudinal valleys that are more persistent than the others, each of which marks a change in the formations which compose the mountains. As far west as the first of these, the structure of the mountains may be understood from the sections*, figs. 11 & 12. The strata are of thick-bedded limestones. These limestones are of dark and light-blue

* All these sections are merely diagrams combining the results of detached observations.

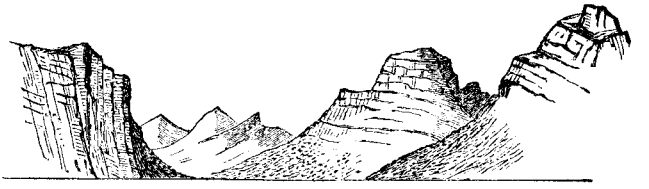
colour, crystalline, compact, or cherty, with fossils that are of Carboniferous age. In the sections these limestones are lettered *b*.



Along with them are softer beds of gritty sandy shale, generally of a dull-red or purple colour; and the irregular disintegration of these

two groups of strata produces the rugged appearance of this range, the mountains being in general formed by masses of synclinal folds, while the valleys mark anticlinal fractures. The valley between the first and second range marks a great trough in the strata in which patches are preserved of chocolate-coloured ferruginous shales with beds of grit and layers of ironstone, and which are the same seen in the above sections resting on the flanks of the limestone mountains, belonging to a more recent formation, and to which I have previously alluded (p. 427). In the second range we have the same limestones and shales repeated as in the first; but at the base I observed traces of a magnesian limestone of a buff colour, containing *Atrypa reticularis*, a true Devonian fossil (*c*, fig. 11). Towards the west this range everywhere in the mountains presents a sheer wall of vertical limestone, the ragged edge of the beds forming the Saw-back Range. The change in the look of the mountains that now takes place may be well seen, as on Bow River in fig. 13, where the east side of this

Fig. 13.—*Sketch of the Second Great Valley, on Bow River, in the Rocky Mountains.*



valley consists of vertical strata, while on the west side the mountains are formed of cubical masses of strata that are almost horizontal. These are of hard quartzite-sandstone, passing into conglomerate, and capped by hard limestone, with the ferruginous shales resting obliquely on their sides at the line of fracture. At the source of the Pipe-stone Creek the mountains form part of the second range, and there I procured some fossils that have been distinguished by Mr. Salter as *Orthis*, *Lingula*, *Euomphalus*, and from the limestone *Lithostrotion*, which are either Carboniferous or Devonian. On the Athabasca River gneissoid rocks, traversed with quartz-veins, were observed to form the floor of the second longitudinal valley, and in descending the valley of Vermilion River, and also that of Blaeberry River, talcose shales were met with also, forming the floor of the valley (*e*, figs. 11 & 14). On Kicking-horse River in the third range, we have the mountains again formed of blue limestone, together with a compact blue schist with red bands, giving a curious striped aspect to the rock. This schist or slate-rock forms the highest points of the mountains in the above district (*d*, fig. 14).

The third longitudinal valley is that in which the Columbia and Kootanie Rivers flow in opposite directions parallel with the range. Along the eastern shore of the Columbia Lakes we find the mountains again composed of the Carboniferous limestones which form the eastern ranges, but resting unconformably on slates (*e*, fig. 14).

At the source of the North Saskatchewan the mountains are very massive, and are principally composed of a deep-blue compact limestone, that often contains nodules of iron-pyrites (*c*, fig. 14). A few specimens of *Atrypa* (*reticularis*?) and *Athyris* lead Mr. Salter to regard these limestones as Devonian. To the west of the great Columbian valley the strata were only seen in descending the Kootanie River, as shown in the section, fig. 14. That river breaks through a succession of well-defined ranges that never rise to any great altitude, and are composed of dark schists (*e'*), traversed by quartz-veins, the whole forming beautifully developed flexures. Some miles east of Padler Lake the slates (*e*) were again seen underlying these schists, and at that place commences a district of granitic country (*f*), where mountain-ridges rise as rounded masses to the height of 800 to 1000 feet above the general level.

Towards Fort Colvile the Kullespellem Mountains bound the Columbia to the east, and are formed of quartzose slates in thin beds, limestone partly altered, and serpentine. At the south end of the Kulespellem Mountains the great trap-flocs of the Columbian Plains commence, and are there seen to overlie the granite and other strata, filling up the hollows in their surface.

The horizontal extent of these lava-flocs is truly wonderful, as they occupy nearly the whole surface of the great Columbian Desert without any chain of mountains or peaks existing to which their origin can be referred.

This great plain is frequently cut by chasms 500 to 600 feet deep, the sides of which expose stratum after stratum of thin lavas intercalated with softer tufaceous beds, the whole being quite horizontal. The lava-flocs have often a columnar structure, especially in the neighbourhood of depressions in the plain, such as Sil-kat-kiva Lake, which probably mark the position of ancient craters. At some points up Snake River, American parties have procured Tertiary fossils from the tufaceous limestone that underlies these basalts.

The whole way to the Dalles the Columbia flows through an enormous chasm in these stratified lavas and tufas, giving rise to most wonderful scenery. Often the whole of this mighty river is compressed between perpendicular walls of basalt, but with a channel of such depth that its treacherously swift current preserves a glassy surface.

CASCADE RANGE.

Where the Columbia breaks through the Cascade Range there is a great rapid rather than a fall, from which the mountains have derived their name, and connected with the formation of which there is an old Indian legend. The river from the Dalles to this point, a distance of forty miles, is almost without current, and bounded by a perpendicular wall of mountains on either hand, and the story is, that at one time the river had a uniformly swift current the whole way, and that where the Cascades now are, it then passed under a gigantic natural arch that crossed from side to side of the chasm. During a great earthquake this arch fell down, and now remains as the chain of islands across the head of the Cascades,

while the river has gradually carried down the fragments so as to form the long rapid. The river was thus dammed back all the way to the Dalles, and submerged the forests along its banks, the stumps of which are still to be seen sticking out of the water at a distance of several hundred yards from the shore. The stumps of the submerged trees are of a species that never grows near water; and as the other conditions of the story agree remarkably well, I am inclined to think there may be some truth in it. It was told me, as we were passing the spot, by a fellow-passenger who had been a long time among the natives as an American Indian agent; and I have since heard it from gentlemen who have been twenty-five years in that country in the Hudson Bay service.

In descending from the Cascades to Vancouver, stratified rocks are seen perched on the flanks of the mountains, among which is a group of strata of a bright vermilion colour. Along the valley of the river there are also strata of tufaceous sandstone and clay which are only slightly disturbed. At the Cascades the beds attain a considerable thickness and contain large fragments of silicified wood. The scenery of the Lower Columbia before reaching the flat district around Fort Vancouver is exceedingly fine, the river passing, successively, bold promontories more than 1000 feet in height, and sometimes under lines of cliff over which rivulets pour as cascades from a height of 600 feet. Between the Olympic or Coast Range, which stretches to Cape Flattery, and the Cascade Range, the great valley of Puget Sound is continued south as far as latitude 44°, first as far as the Columbia River by the Cowlitz Valley, and then by the valley of the Willamette, and presents a long strip of valuable country, which forms the only good part of Oregon and Washington territories. The River Columbia crosses this strip of country, only conforming to its direction for a short way from Vancouver to the Cowlitz.

Of the Olympic Range I believe nothing is known; but, as viewed from Puget Sound, the outline of these mountains reminded me in a striking manner of that of the exterior ranges of the Rocky Mountains, where they are composed of plications of stratified rocks.

I have previously mentioned the metamorphic rocks, with beds of crystalline limestone, that form the mass of Vancouver Island; and for further interesting details respecting the south end of the island, reference may be made to Mr. Bauerman's paper, published in the Society's Journal, Nov. 1859.

April 24, 1861.

Daniel Mackintosh, Esq., Chichester, and Richard Payne Cotton, M.D., F.R.C.P. Lond., 46 Clarges Street, Piccadilly, were elected Fellows.

The following communications were read:—